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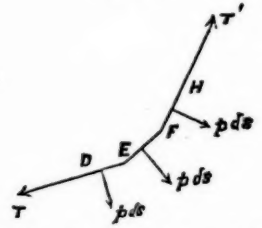
THEORY OF ARCHES.

(*Continued from page* 104.)

Again, take *three* elements, D E, E F, F H (Fig. 16), of the cord, each bearing the

Fig. 16.

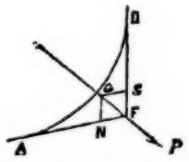


normal load $p\,d\,s = p\,d\,s = p\,d\,s$. In place of the little arcs, we use for clearness the chords of those arcs. Since the load around the whole curve C A B (Fig. 14) is supposed to be *uniform*, the arcs bearing the equal elements ($p\,d\,s$) of that load must also be equal, or D E = E F = F H. We have above proved T = T'. Hence the three sides D E, E F, and F H will arrange themselves symmetrically as in (Fig 16). Now, every other piece of the cord containing three elements will assume exactly the same slope as D H, since each such piece must equal D H in length and must be acted on by an equal and precisely similar system of forces. Consequently, the little chords D E, etc., must constitute a *regular polygon*, and the curve in which they are inscribed must be *constant* in curvature, in other words—a *circle*.

Therefore the curve of the cord C A B (Fig. 14) is the arc of a circle.

To form the triangle of forces for any point of a loaded circle as for A D (Fig. 17),

Fig. 17.



draw the tangents at the extremities A and D. From the intersection, F, of these, lay off F N = F S, to represent the equal pulls at A and D. Then the diagonal F G=the resultant of the load, and the triangle F N G or F S G represents the forces acting on A D.

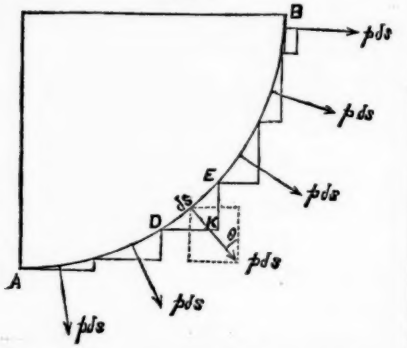
It is often easier to deal with a *uniform normal* load by resolving it into its vertical and horizontal components. The load on an element D E = ds of the quadrant A B (Fig. 18) is = $p\,d\,s$. The horizontal component of this load = $p\,d\,s$ sin. θ, where θ = the angle made by the direction of pds with the vertical (or what is the same, the angle made by the tangent of ds with the horizontal). The vertical component = pds cos. θ. Consider the horizontal component (pds sin. θ) with reference to the vertical space over which it is distributed. This space is E K (Fig. 18)= $d\,s$ sin. θ. Hence the *intensity* of the horizontal component

$$= \frac{p\,d\,s \sin\theta}{d\,s \sin\theta} = p.$$

So the vertical component ($p\ d\ s\ \cos\ \theta$) is distributed over a horizontal space = D K $= d\ s\ \cos\ \theta$, and therefore its *intensity* is

$$= \frac{p\ d\ s\ \cos\ \theta}{d\ s\ \cos\ \theta} = p.$$

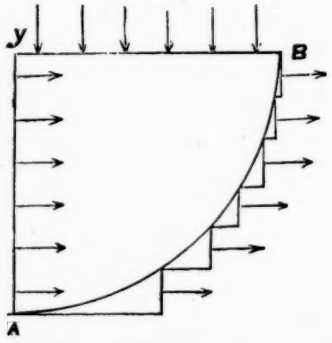
Fig. 18.



But p = the *intensity* of the normal force. Hence the original normal force at each point is equivalent to a horizontal and a vertical force, at that point, of equal intensity.

If we then construct little triangles on the curve A B (Fig. 19) such that their

Fig. 19.



vertical sides shall be constant in length, the horizontal forces on these sides will be represented by lines of constant length. Transfer these forces in their lines of direction to A Y. A Y is the sum of all the vertical sides of the little triangles, and as the horizontal *intensity* is constant and equal to p, we have (if r = radius of the circle) p (A Y) = pr = total horizontal force on quadrant A B.

Similarly, if we draw a set of triangles on A B with all their *horizontal* sides of the same length, we may see that the total vertical force on A B is

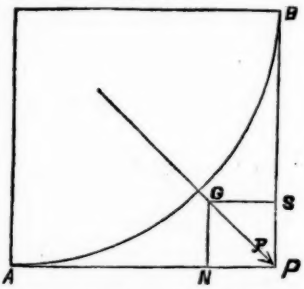
$$= p\ .\ (\text{Y B}) = p\ r.$$

Hence,

1. The resultant of the entire normal force on the quadrant A B is equal to the resultant of a horizontal and a vertical force each of which is = pr.

2. Therefore in the parallelogram of forces for the quadrant (Fig. 20), F S,

Fig. 20.



which represents the pull along the cord at B, is the vertical component of P, while N F = pull at A, is the horizontal component of P. Each of these forces = pr. Therefore the constant pull all along the cord is = pr.

If we make the pull at the vertical point (B) = V, we have

$$\text{H} = \text{V} = \text{T} = p\ r \quad . \quad . \quad (20.)$$

In practice a uniform normal force exists in the case of a cylinder filled with steam, or in a vertical cylinder filled with liquid Thrust instead of tension along A B exists when the normal force pushes inwards, as in the tubes of a steam boiler or an empty vertical cylinder immersed in water. In reference to arches, this discussion has its principal value as introductory to those that follow.

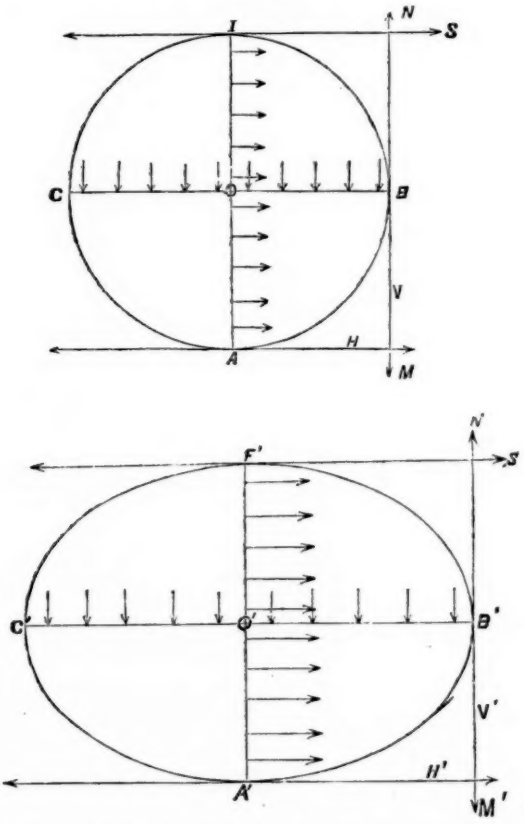
Case V.—In this case we obtain the curve and forces by parallel projections from the circle.

If we suppose a cylinder erected upon the circle (Fig. 21) as a base and cut it by an inclined plane whose line of intersection with the plane of the base shall be parallel to A I, we will get an ellipse whose vertical axis A′ I′ (Fig. 21) will = A I, and whose horizontal axis C′ B′ will be greater than

C B. All lines parallel to A I will be unchanged in length, while all parallel to C B will be increased in the proportion of C′ B′ to C B. Now, by the principle of parallel projections, the ellipse, which is the parallel projection of the circle, will be balanced under the forces which are the parallel projections of those under which the circle is balanced.

As we have seen, the circle is the curve assumed by the ring under a uniform horizontal and vertical force at each point of the same kind, and equal in intensity; for such a system of forces is equivalent to a constant normal force around the curve. For convenience, these forces are represented in Fig. (21) along the two diameters, each little line representing the force on a unit

FIG. 21.



of distance. The pull around the ring is of course tangential to it, and is everywhere the same ($= pr$). This pull is represented at A and B by the arrows there.

In the ellipse, the *vertical* lines being unchanged, the total vertical force on the elliptic ring (= the sum of all the little vertical lines) is the same as it was in the circle, and if we call the vertical force on a quadrant V (= B M) for the circle and V′ (= B′ M′) for the ellipse, we will have

$$V = V' \quad . \quad . \quad . \quad (21.)$$

Notice, however, that in the ellipse the force V′ is distributed over the distance O′ B′ and not over a distance = O B. Hence the *intensity* of the force V′, or the amount of that force on each unit of distance, is not

the same as in the circle. In the ellipse (Fig. 21) each little vertical line represents, therefore, the force on a distance greater than a unit. Let $O'B' = c\ OB$. Then to obtain the *intensity* of V', divide it by the space over which it is distributed. Thus, let

$$p_y = \frac{V}{O\,B} \text{ and } p_x = \frac{H}{A\,O}$$

represent the vertical and horizontal intensities in the circle. We have already seen that in the circle

$$p_y = p_x = p.$$

Let p'_y and p'_x represent the vertical and horizontal intensities in the ellipse. Then

$$p'_y = \frac{V'}{O'\,B'} = \frac{V}{c\ O\,B} = \frac{p_y}{c} \qquad (22.)$$

The lines representing the "pulls" at B and C (as B N) are also unchanged. Hence the pulls at those points in the elliptic ring are the same as in the circular; that is they are equal to V' = V.

The *horizontal* lines are all increased in length in the ratio 1 : c. Hence the sum of the lines representing the horizontal force on a quadrant of the ellipse (as I' S') is greater than the corresponding line (I S) in the circle in the above ratio. Therefore if H' = the horizontal force on the elliptical quadrant,

$$H' = c\,.\,H \qquad . \qquad . \qquad (23.)$$

The length over which this force H' is distributed (A' O') does not change, however, and hence the little horizontal lines in both figures represent the force on a unit of distance. Hence the *intensity* of the horizontal force in the ellipse has increased just as the length of the lines, or from the equation.

$$p'_x = \frac{H'}{A'\,O'} = \frac{c\,H}{A\,O} = c\,p_x \qquad (24.)$$

The horizontal pull in the ring at A' or I' being equal to the horizontal force on a quadrant is

$$H' = c.H = c.V = c.V' \qquad . \qquad . \qquad (25.)$$

Hence the "pull" around the ellipse is *not* constant as it was in the circle. The pulls at B' and A' are as

$$V' : H' :: 1 : c$$

But

$$A'\,I' : C'\,B' :: 1 : c.$$

Therefore,

1. The pulls in an elliptical ring are as the axes to which they are parallel.

Again the intensities in the ellipse are

$$p'_y : p'_x :: \frac{p_y}{c} : c\,p_x :: \frac{1}{c} : c :: 1 : c^2$$

And

$$(A'\,I')^2 : (C'\,B')^2 :: 1 : c^2$$

Therefore,

2. The *intensities* of the forces in an ellipse are as the *squares* of the axes to which they are parallel.

From this proportion we have

$$c = \sqrt{\frac{p'_x}{p'_y}} \qquad . \qquad . \qquad . \qquad (26.)$$

It will be noted in the elliptic ring that the resultant of the little horizontal and vertical loads at any point is not *normal* to the curve except at the extremities of the axes.

Let us determine the pulls and the relations between the forces at other points besides the extremities of the vertical and horizontal axes of the ellipse.

In the circle (Fig. 22) if we resolve the forces along any two rectangular axes as $A_1\,I_1$ and $C_1\,B_1$, we shall have evidently the same relations between them as when resolved along a vertical and horizontal axis. Now the three parallel lines, viz., the diameter, $A_1\,I_1$, and the tangents at C_1 and B_1, are projected in the ellipse into three *parallel* lines, viz.: A'_1, I'_1, and the tangents at C'_1 and B'_1. Similarly C_1, B_1, and the tangents at A_1 and I_1 continue parallel in the ellipse. Hence *rectangular* diameters of the circle become *conjugate* in the ellipse. The lines representing the forces perpendicular to $C_1\,B_1$ in the circle become parallel to $O'\,I'_1$ in the ellipse, and are changed in length just as $O'\,I'_1$ is changed from $O\,I_1$. So the forces which are parallel to $C_1\,O$ in the circle become parallel to $C'_1\,O'$ in the ellipse, and vary as $C'_1\,O'$ does from $C_1\,O$.

Let $O'\,I'_1 = r'$ and $O\,C'_1 = r''$ and let the total force parallel to $O'\,I'_1$ on a quadrant (such as $C'_1\,I'_1$ or $I'_1\,B'_1$) of the ellipse be = V_1 and that parallel to $O'\,B_1'$ be = H_1. Then if r = radius of the circle, we have (since the force on a quadrant of the circle as $C_1\,I_1$ is = H = V = T)

$$\left.\begin{array}{ll} H : H_1 :: r : r'' & \therefore H_1 = \dfrac{H.r''}{r} \\ V : V_1 :: r : r' & \therefore V_1 = \dfrac{V\,r'}{r} = \dfrac{H.r'}{r} \\ & \therefore H_1 : V_1 :: r'' : r' \end{array}\right\} \qquad (27.)$$

H_1 is equal to the pull along the ring at A'_1 or I'_1, and V_1 is that at C'_1 and B'_1.

Hence *proposition* 1 may be applied gen-

erally to all conjugate diameters in the ellipse; that is,

3. The total pulls along the ring at the extremities of any two conjugate diameters, are as the diameters to which they are parallel.

Again, the *intensities* being equal to the total loads divided by the surfaces over which they are distributed, let

p'_{y_1} = intensity of load parallel to O′ I′$_1$,

p'_{x_1} " " " C′$_1$ O′

Then

$$\left.\begin{aligned} p'_{y_1} &= \frac{V_1}{O'C'_1} = \frac{V\,r'}{r\,.\,r''} = p_y\,\frac{r'}{r''} \\ p'_{x_1} &= \frac{H_1}{O'\,I_1'} = \frac{H\,r''}{r\,.\,r''} = p_x\,\frac{r''}{r'} \\ \therefore p'_{y_1} : p'_{x_1} &:: p_y\,\frac{r'}{r''} : p_x\,\frac{r''}{r'} :: \frac{r'}{r''} : \\ &\quad \frac{r''}{r'} :: r'^2 : r''^2 \end{aligned}\right\} (28.)$$

Hence for *proposition* 2, we may read,

4. The *intensities* of a pair of conjugate loads are to each other as the *squares* of the conjugate diameters to which they are respectively parallel.

To pass from one set of conjugate forces on the ellipse to another; let

p'_{x_1} and p'_{y_1} be the intensities parallel to one set of conjugate diameters.

H_1 and V_1 be total pulls parallel to same set of conjugate diameters.

r'' r' be the conjugate semidiameters.

Also let

$$p'_{1x_1},\ p'_{1y_1},\ H'_1,\ V'_1,\ r''_1,\ r'_1$$

be the corresponding quantities for the other set. Then

$$\left.\begin{aligned} p'_{x_1} &= p_x\,\frac{r''}{r'} \qquad \therefore\ p_x = p'_{x_1}\,\frac{r'}{r''} \\ p'_{1x_1} &= p_x\,\frac{r''_1}{r'_1} \quad \therefore\ p'_{1x_1} = p'_{x_1}\,\frac{r'\,r''_1}{r'_1\,r''} \\ \text{Also,} & \\ H_1 &= \frac{H\,r''}{r} \qquad \text{or } H = \frac{H_1\,r}{r''} \\ H_1' &= \frac{H\,r''_1}{r} \qquad \therefore\ H'_1 = \frac{H_1\,r''_1}{r''} \\ \text{Similarly} & \\ p_1'_{y_1} &= p'_{y_1}\,\frac{r''\,r'_1}{r'\,r''_1} \\ V_1' &= V_1\,\frac{r'_1}{r'} \end{aligned}\right\} (29.)$$

The ellipse (Figs. 21 and 22) is the form assumed by a cord under a load composed of horizontal and vertical components which are constant along the horizontal and vertical lines, but which differ from each other in intensity.

The diameter C′ B′ of the ellipse (Fig. 21) might have been made *shorter* instead of *longer* than that of the circle, if required.

Cor.—If one set of the forces are vertical and the other not horizontal, but inclined at an angle to the horizon (Fig. 23), we still have an ellipse, the directions of the forces giving the directions of two conjugate diameters (A′$_1$ O′ and B′$_1$ O′). Then, if p'_{x_1} = the intensity of the inclined force and p'_{y_1} = intensity of the vertical force, we have by proposition 4,

$$p'_{x_1} : p'_{y_1} :: (B_1'\,O')^2 : (A_1'\,O')^2$$

So from proposition 3, if V_1 = pull along the cord at B$_1$′ or C$_1$′ and H_1 = that at A$_1$′

$$H_1 : V_1 :: B_1'\,O' : A_1'\,O'.$$

From the first of these propositions we have the ratio of the conjugate diameters; and from the second we find the pulls at the extremities of those diameters.

Knowing two conjugate diameters and the angle $(90°-j)$ between them we can readily obtain the ellipse.

To obtain the pulls at the extremities of any diameter, such as C$_1$ B$_1$.

This is merely passing from one set of conjugate diameters to another and equation (29) gives the pull at B$_1$, for instance, as

$$V_1' = V_1\,\frac{O'\,K}{O'\,A_1'}$$

(O′ K being conjugate to C$_1$ O′ B$_1$), etc., etc.

An important fact is now to be noted. Whenever the load on a cord is entirely *normal* to it, at that point the pull along the cord is equal to the intensity of the normal load multiplied by the radius of curvature.

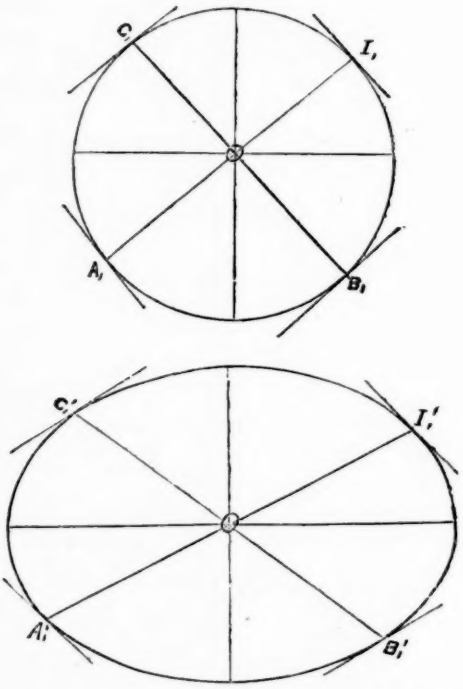
For the cord *at that point* is similarly situated to a circular cord of the same curvature and under a load of the same intensity.

Thus, in the ellipse (Fig. 21) the action of the load at the extremities of the axes is entirely *normal*, for at A′ and I′ the horizontal component of the load vanishes and leaves only the vertical, which, *at these points*, is *normal* to the curve. So at C′ and B′ only the horizontal load has value, and its action is there normal to the curve.

Consider the elementary arc, *ds*, at A′, for instance, which is subjected to this normal load. It is balanced under the equal

pulls T = T′ (Fig. 24) coming from the adjoining parts of the cord, and the normal load *pds*, which gives it its curvature. Imagine a circle under a constant normal force of intensity = *p*. Take an equal little arc *d s* of it, loaded with a normal load =

FIG. 22.



pds. Then, if it be acted on at its two ends by tensions = T = T′, it is evident that it will have the same curvature as the arc of the ellipse; or, conversely, if it has *the same curvature*, the pull around the circle *must* be = T = T′.

Hence, having given the load on the curve at any point where it is *normal*, we determine easily the pull along the cord at that point. For, in the circle,

$$H = V = T = p_z\, r = p_y\, r = p\, r$$

and in the ellipse at A′

$$H' = p'_y\, \rho$$

Where ρ = radius of curvature. If A′ O, = *r* and O′ B′ = *c r* in the ellipse (Fig. 21) we have at A′

$$\rho = \frac{c^2\, r^2}{r} = c^2\, r.$$

$$\therefore H' = p'_y\ c^2\, r = \frac{p_y}{c}\, c^2\, r = c\, p r = c\, H. \quad (30.)$$

So in the parabola under uniform vertical loads (Case I.) we have seen that H = 2 *p m* (Rankine's C. E. p. 165). But H = *p* ρ = 2 *p m* (since ρ = 2 *m* at the vertex).

If the load be *everywhere* normal to the cord, the above equation will apply to every point, or

$$T = p\, \rho$$

be a general equation of the curve.

And further, when the load is everywhere normal we have already seen that the pull along the cord must be *constant*, as there is no tangential force to change it. Hence.

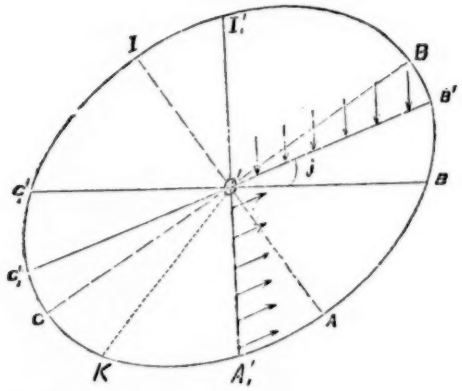
$$T = p\, \rho = \text{a constant.} \quad (31.)$$

When the load *p* is constant, of course, ρ must be constant too, and we have the circle already discussed. When *p* varies, ρ must *vary inversely* as *p*.

Case VI.—If *p* increases in value just in

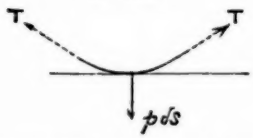
proportion to the distance of the points of the cord above a horizontal line M N (Fig. 25), the cord assumes the shape of the hydrostatic arch. This curve possesses geometrically the loops shown in the figure and may be extended indefinitely, but for

FIG. 23.



our purpose it is evidently only necessary to discuss that part between the points C and B (Fig. 26) where the tangents are vertical.

FIG. 24.



Taking L (Fig. 26) for the origin, if the intensity of the load then be y_0 (= A L) multiplied by a constant, or wy_0, then at any other point it is = wy.

Hence the equation of the curve is

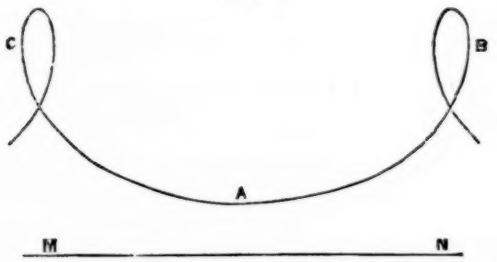
$$T = p\rho = w y \rho = w y_0 \rho_0 = \text{a constant}$$

(y_0 and ρ_0 are the values of the ordinate and radius of curvature at A).

Let us resolve the normal load on C A B as we did in the circle, into its horizontal and vertical components. As was the case in the circle, these will be *for each point* equal in *intensity* to each other and also to the *normal* force, or

$$p = p_x = p_y.$$

FIG. 25.



But these quantities are no longer constant (as in the circle) all along the curve, but vary from point to point.

If we form the parallelogram of forces for any arc A D (as in Fig. 27) the side N F = F S, since H = T = a constant, and F G must represent the resultant of the whole load on A D both in amount and direction.

The vertical component, F E of F G, is equal to the vertical component S X of S F, or

Vertical load on A D = T sin i = H sin i.

At B the vertical load $= T = H = V$ (since $i = 90°$ there).

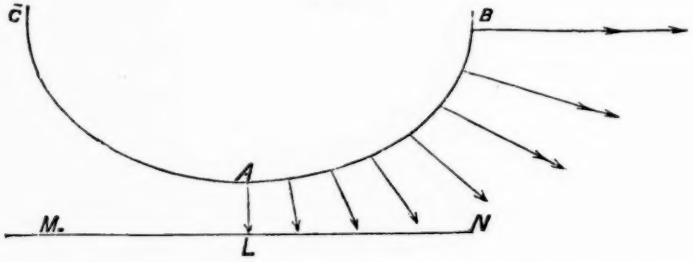
So the horizontal component of the total load on A D is G E, and since

$$N F = G S = G E + F X$$

we have horizontal load on

$$A D = G E = N F - F X = H - H \cos i = H (1 - \cos i),$$

FIG. 26.



At B, $i = 90°$ ∴

Horizontal load on A B $= H$

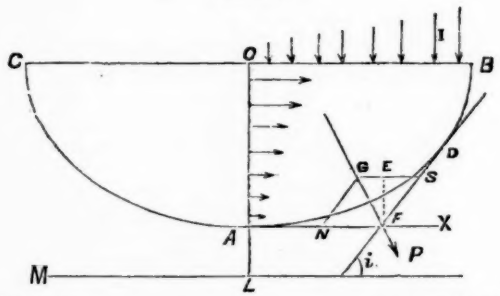
On the arc D B

Horizontal load $= H - H (1 - \cos i) = H \cos i$.

The *vertical* load on A D may be thus expressed

$$H \sin i = \int_0^x p_y \, dx = w \int_0^y y \, dx = w \, y_0 \, \rho_0 \sin i \quad (32.)$$

FIG. 27.



The *horizontal* load thus

$$H (1 - \cos i) = w \, y_0 \, \rho_0 (1 - \cos i) = \int_{y_0}^{y} p_x \, d \, y =$$

$$w \int_{y_0}^{y} y dy = w . \frac{y^2 - y_0^2}{2} \quad (33.)$$

And if y_1 = ordinate of B, the horizontal load on A B is

$$H = w \frac{y_1^2 - y_0^2}{2} \quad (34.)$$

For formula for radius of curvature see Rankine, C. E., p.

The equation $T = H = w \, y_0 \, \rho_0 = w \, y \, \rho$, enables us to solve problems similar to those under the parabola.

(To be continued.)

NOTES ON IRON.*

BY THOMAS MORRIS, Manager of Dallam Forge, Warrington.

From "Iron."

What is this material called iron—this most useful of all metals—the intrinsic value of which exceeds all others, and which, in proportion to its use, should be the cause of progress of civilization in the world wherever it is manufactured—a substance whose extent of consumption any by nation,

* Read at the Warrington Literary and Philosophical Society.

both in times gone by and at the present day, indicates very truly the degree of its advance in the arts and sciences? If we ask the geologist, he tells us that it impregnated the waters of the old red sandstone period, and tinged with rusty red the whole of that system; that it now appears in the segregated form of thin layers and bands of ironstone; that its ores are found more or less in all parts of the world, either as beds in the sedimentary rocks, or in the massive deposits in the olden rocks; that the United Kingdom derives its principal supply from the earthy carbonates of the coal measures, from the carboniferous formations where some particular coal-fields possess large deposits of rich hæmatite ore —instance the Cumberland and Lancashire district; from the oolitic beds of Cleveland and of South Yorkshire, where it is found from a few inches to 20 and 30 ft. thick; and those extraordinary carbonaceous blackband ores of Scotland where the richest deposits hitherto discovered are found. The meteorologist tells us the sun and the atmosphere played a most important part during the carboniferous era, and that now we are consuming the bottled-up sunlight of millions of years past in the making of iron. Again, iron in the shape of falling meteors has been found, and from one of these bodies a Persian Emperor had made two sabres, one knife, and one dagger. This "iron of lightning," or thunderbolt, could not be worked up by itself, but must have been mixed with one-fourth of common iron before the Tubal Cain of that day did his master's bidding. It would be a wrinkle worth knowing how he obtained the mixture. The mineralogist has been consulted, and he simply says that he has given us the various degrees of hardness of minerals, determined the idea of the species, and fixed the principle of classification. Coming to our nearer friend the metallurgist, he lets us know the numerous combinations and analyses of the particular metal we wish to study; what mechanical and chemical sciences are involved to complete the separation of the metal in that condition of purity desired by the manufacturer; what flux will best suit to form a glass with the multifarious ores during their fusion in that huge laboratory, the smelting-furnace. He tells us that without flux to separate the earthy matter from the ores, glasses would be formed, instead of the carburet of iron, and slags, and that the best known flux for nine-tenths of the ores is limestone, which is incapable of holding iron in solution at high temperatures; that there must be blown under pressure from 6 to 10 tons of atmospheric air in the furnace to produce the required oxygen for the reduction of 1 ton of pig-iron from the ore. Besides this, he can, if he will, tell us his utter inability to produce the same quality, or the same quantity of iron during the smelting process from two different ores. Yes, all his skill in the science of chemistry, his numerous experiments and analyses, have signally failed to furnish him with this grand object. Undoubtedly his assiduity in the science of chemistry has taught him judiciously to mix the ores given him by nature, and thereby to produce a suitable article for his customer; but inasmuch as the ores differ in their component parts, as the coal or fuel differs in its constituents, whether he uses hot or cold blast, so does he give us a cast metal commercially called pig-iron, at the price it will fetch in the market. And it is from this market that the finished iron manufacturers (as in Warrington) take it in hand, and by two distinct processes convert it into bars, plates, wire, etc.

We have arrived now at the puddling process, which is replete with interest, consisting as it does of converting cast metal into malleable iron. The present system of puddling as carried on almost universally with few modifications (which shall be named), was invented by an iron-master of the name of Cort, about the year 1780, the bed of whose furnace was made of sand. When the carburet of iron was refined, many of its impurities (especially the carbon, which is the metalloid causing fluidity) were driven from it; hence when the pig-iron was melted, it assumed the form of grain. If the carbon had been left in the pig-metal, the bed of the furnace could not have stood; besides, silica is fatal to iron, causing what is technically known as shortness or extreme brittleness. The deteriorating influence which sand or silica had on the iron when worked in contact with it was seen some years afterwards by Mr. Samuel Baldwin Rogers, who introduced the present system of iron bottoms to furnaces, which eventually did away with the finery process. Both of these gentlemen died in poverty, yet their inventions in their day were as much a desideratum, and were the cause of greater revolutions in the iron trade of that time than the Bessemer pro-

cess or Danks' rotary puddler in our time. Mr. Joseph Hall, of Tipton, introduced the present pig-boiling process, doing away with the refining process. Many imagine that the gentleman with the cloven foot invented puddling, and I confess that for four or five months in the year it is one of the most distressing processes to the physical system of all manual labor, yet puddlers don't all stagger from the furnace fainting at the age of forty, as a certain special newspaper commissioner would have us believe. These joint inventions were the means of this kingdom taking the lead of all other nations in the iron trade, for up to this time we were dependent for our supplies upon Norway, Russia, and Sweden; from the latter place, even now, a large amount of their produce finds its way into England.

In describing this puddling process, it should be explained that the furnace is divided into two compartments, separated by a bridge about 12 in. thick and 14 in. high. Over this the flame passes from the grate and comes in contact with the iron, and after it has done duty there passes around the boilers, generating the steam necessary for driving the machinery required for forging and rolling the iron. The chamber or compartment into which the pig-metal is charged consists of iron plates, forming the bottom and sides, which are lined with refractory slags, rich in oxides of iron. In changing the heat, slags and scales from the hammers and rollers are thrown on the hearth or bottom, and on this the charge of pig-metal, consisting of 510 lbs. to 540 lbs. Fuel is then thrown in the grate, and in about 25 or 40 min. this carburet of iron becomes liquid, and assumes the form of a molten plate of iron some $1\frac{1}{2}$ to 2 in. thick. Being heavier than the slags, the latter pass through it and rise to the top. In passing, the oxygen of the silicates combines with the carbon of the iron and decarbonizes it, but unless the iron is agitated it would not become malleable. Hence the puddler, with a bar called a rabble, agitates the metal, thus bringing the oxygen of the silicate in contact with the carbon and other impurities of the iron. As the carbon is leaving the metal its atoms expand and become of less specific gravity, and it throws off carbonic oxide gas, the blue flame of which is plainly seen by any one who watches the process. The puddler at this stage must be incessant in his operation, for the transformation scene is coming, and the crude iron is becoming malleable. The boiling of the mass is kept up by the fresh energy of the puddler, until, as the carbon diminishes, the atoms of the iron begin to knit or agglutinate together in a soft spongy consistency, the cinder taking the place of the once molten iron. The iron is now as sensitive to oxygen as the human lungs would be if inhaling pure oxygen; it lives, as it were, too fast. It is at this point the smoke-preventers are puzzled, but a deoxidizing flame is kept on the iron while it is being kneaded and divided into balls preparatory to being brought out of the furnace; which when done, the lump is taken to the hammer and beaten into the required shape for rolling it into the puddled bar of commerce. This operation is called shingling.

From what has been said you will readily understand that the puddling operation consists of chemical combinations and mechanical application; and the inventions brought forward to assist the puddler in his part of the business are legion. The schemes tried to prevent smoke, save fuel, etc., etc., may be counted by scores. Quacks by the dozen have sprung up with physic to throw in the molten iron during the process, to drive off the deleterious substances, the one idea being that the iron would have a greater affinity for their dose than it had for the metalloids, carbon, phosphorus, and silicon, and so leave the iron pure. None of these recipés, however, have been so effectual as to warrant their continued and general use. Mr. Bessemer, some twenty-five or thirty years ago, accomplished the grand idea of forcing air through a molten mass, anticipating that the oxygen of the air would decarbonize the carburet and give him malleable iron; but he failed, for when the iron had given up its last equivalent of carbon to the oxygen it commenced to burn it up. Besides, it lacked the kneading, or mechanical part of the operation. The chemical part he got over so far as to produce a metal thoroughly tenacious; and its resistance to wear proves it to be the most durable and economical material for railway and other purposes. This invention of Bessemer's awakened metallurgists, and gave rise to several inventions for steel-making, but up to the present time there is only one invention of any practical importance, and that is the Siemens-Martin process.

About the same time as Bessemer was completing his inventions two gentlemen, Mr. Tooth, of London, and Mr. Walker, of Wolverhampton, brought out patents for oscillating and rotating puddling furnaces, which proved a step in the right direction. Somehow they got across, and their scheme was going when Mr. Menelaus, of Dowlais, bought up their rights, built a forge, and made some good iron. But he found several obstacles in his way, the principal one being the lining of the furnace, which he could not get to stand the severe wear and tear of the metal, and on this rock he came to grief. But this rotary principle had made its impression upon the minds of many people in this country and in America, and more especially upon Mr. Danks. This gentleman was born in West Bromwich, South Staffordshire. He was a puddler by trade, but left that part of the country at the age of twenty for Scotland. After working there three or four years he went to America, and was eventually engaged in the Cincinnati Railway Ironworks Company as their Superintendent. In 1868 this representative of English thought and skill, assisted by American cash and enterprise, built the first experimental rotary furnace, differing from that of Mr. Menelaus only in the flue of the furnace being movable. So significant was this improvement that it led to success, and the patent is now being worked in many parts of England and on the Continent. Complete puddler as is this furnace, it has the fault of producing only one ball, whatever the charge may be. And to produce balls of 100 lbs. or 200 lbs. weight only by this machine would increase the cost of its production. The rolling machinery employed at the present day is only calculated to forge and roll this weight of ball; hence the iron manufacturer, whose production consists of small bars, sheets, and hoops, cannot apply it.

Before leaving the puddling operation I should mention another very interesting principle of making iron which is undergoing a crucial test as to its commercial practicability, and that is a plan worked by Messrs. Gerhard and Caddick, of Bradley, South Stafford, who say that the bloom is made direct from the ore (mark, no smelting, and 50 to 60 per cent. of coal saved), which, having been ground, is mixed with lime and pitch, and then baked in a coke oven. This becomes the pig iron. A furnace is charged with it, and in half-an hour the charge is ready for the hammer. Elba and Barrow iron is at present being used, and excellent finished iron is being turned out.

We have now got to the puddled ball, in which, although it has been kneaded, the particles are in a very loose state, and require the repeated blows of the heavy forge or steam hammer, to knock out the slag which still attaches itself. Truran says the puddled ball is like grains separated by a thin film of extraneous matter (cinder), and when shingled the grains are brought closer together. When rolled into a bar 12 ft. long, each particle is about 9 in. long. Cut this bar into lengths, pile and roll, and we find in one inch of its section as many threads or fibres as were seen in 80 in. of the ball. Truran would have us assume that all iron is fibrous in the puddled bar, and consequently that it must be fibrous in the finished bar. This is a mistake, for often enough the puddled bar is crystallized, and no matter how many times this class of iron is worked over again, fibres cannot be developed. I have mentioned the fibrous bar, which is tough and ductile, hot or cold; and the cold short or crystallized bar. But there is the "hot short" quality; and this class of iron is as much to be guarded against as the cold short. For while the engineer who is constructing a bridge or building a vessel dreads the cold short iron, so does the blacksmith and the boiler maker dread the hot short. The iron manufacturer is the greatest sufferer from this class of iron, for after the iron has passed all its processes, its characteristics are seen in the finished iron in the shape of small cracks, at times so minute that an experienced eye only can detect them, and when found, the bar must be thrown to the scrap heap. Indirectly, too, the iron-master comes in for blame and cost, for if this defect is not detected before leaving the works, and the consumer does not find it working hot to the shape he requires, he immediately demands compensation from the manufacturer, or returns the iron upon his hands. In Wales, at one time (it is somewhat improved now), iron was so short when red, that the rough or puddled bar would drop in pieces while rolling at the forge rolls. The method of working up these short bits into finished iron, principally rails, was to make a large pile, and having a full-sized bottom to start from, it was built up to the required weight. In this manner the commonest of iron made from the lowest of ores,

containing a large amount of iron pyrites, was worked up and made suitable for rails. Makers of high-class iron are very careful to avoid this. Red short iron is that which cracks when bent or punched at a red heat, although it may be sufficiently tenacious when cold. Cold short iron, on the contrary, is weak and brittle when cold, but can be worked without difficulty when hot.

The puddled bar is now before us, and must go through process No. 2 before it is fit for commercial uses. Hence it is cut down into suitable lengths, taken to the finishing mill, when it is piled up to the weight wanted, and charged in furnaces on bottoms made with sand. When at a welding heat, it is brought out and taken to the rollers again, and reduced to every imaginable shape or section desired by the customer.

We have now arrived at the finished or merchant bar; and leaving the iron-maker we will for a few minutes consult the engineer and theorist and learn what they have to say. The theorist imagines that by repeated workings all iron must be improved in its quality. This theory is wrong. Engineers and others state that all iron is subject to singular and important changes in its structure, and becomes crystallized. The causes they give for this molecular change are vibration, percussion, heat, magnetism, frost, or extreme cold. Many of these gentlemen found their belief on the remarks of others, without making a single experiment or observation of their own. And, therefore, for our better understanding them I shall give you some extracts taken from the "Transactions of the Institution of Civil Engineers" dated 1843.

Extract 1. Samples of broken axles were exhibited; some of them, being cut from different parts of the same axles, showed that at the journals, where the vibration was the most intense, the crystallization was increased to a great extent beyond what occurred in other parts of the same axles.

Extract 2. Mr. Moreland had frequently noticed that pins for chains, and pump rods, although of the best iron, would, if subjected to concussion, after a certain time, break suddenly, and that the fracture would exhibit a large crystallized texture. This was also frequently observed in the broken axles of road carriages, although they were generally made of iron of the finest quality.

Extract 3. Mr. Lowe stated that at the gas works under his direction wrought-iron fire bars, although more expensive, were generally preferred; a pan of water was kept beneath them, the steam from which speedily caused them to become magnetic; he had frequently seen these bars, when thrown down, break into three pieces with a crystallized fracture.

Extract 4 is from the "Engineer" some three and a half years ago. A paper was read by Mr. Peter Carmichael, in which he gave the following as a reply he got from the makers of two boilers he wrote about: "From experience the firm found that all qualities of iron got hard and brittle after the boilers had been at work more than a dozen years, more especially when exposed to the action of the fire, and that in the furnaces, even Lowmoor or Bowling iron becomes as brittle as common iron in that time, and great care has to be taken in making repairs to prevent plates from cracking. For this reason they thought sixteen to seventeen years a long enough period for a boiler to be in use, at a pressure of 40 to 45 lbs. to the square inch. If used for a longer period the pressure ought to be lowered." I must not omit to say that Mr. Carmichael says that the plates had become very brittle although made of Glasgow best iron for shell, and for flues Glasgow best scrap.

These extracts give us opinions of the different purposes for which iron is used. And they imply that the iron was good and fibrous, that the iron manufacturer was of known repute, etc. All this is very good for the iron-master, because it exonerates him from all blame, and in reality no blame can be attached to him if he has fulfilled the contract entered into between him and his customer. Now it is somewhat strange that not one of these extracts gives us any data, or proof to guide us in forming a reliable conclusion. Assuming that these gentlemen believed that the axles, the pins for the pump rods, or the crank pins, the grate bars, and the boiler plates were from well-known makers; that the axles did turn up nice and soft, showing a long turning, the pins forged well and turned up bright, the grate bars and the boiler plate were from best iron and best scrap, no man can say on looking at these finished articles that they were tough and fibrous, unless he had watched every working carefully, or had the adjacent scrap tested, and if he breaks the article he

destroys it, and must replace it. However, the user has bought them, and these things must, and are, put to do duty. And when they have done duty, they have not all broken. No! for not one axle or crank pin in a thousand breaks, because they have become crystallized through vibration. Nor does the grate bar, because the steam has magnetized it; while the boiler plate becomes hard and brittle, only so far as its atoms have been disturbed after leaving the mill and previous to being riveted up. But if one of these axles, tires, rails, crank pins, etc., breaks, though only one in a thousand, it is put down to vibration, extreme cold, excessive heat or magnetism, by those people who endeavor to account for every phenomenon, but who rarely succeed in proving anything.

If you require proof of my assertions, I give you what I consider proof, and invite discussion, in the belief that something may be learned from it. I have seen axles worn out, some of them broken at the journals, because worn under original size, which could scarcely be broken in the middle; and after breaking, the fracture shows the build of the pile or faggot the axle was made from. Some part of the fracture being beautifully fibrous iron, the other part crystallized. If vibration causes crystallization, how is it each particular part of the pile has not become the same? Scores of axles were bought by a firm not far from here for old scrap; they could not be re worked until they were cut into halves. The firm essayed to break them by pulling them up 16 ft. to 18 ft., and letting them fall on their middle across a piece of metal. This failed, with few exceptions. It was tried to break them by letting a ton weight drop upon them. This gave similar results, failing also; and had there been no other means of getting this very good scrap in half it would have been dear at a gift; therefore they were not brittle by vibration. The journal of an axle being the extreme end of the forging, gets too often more fire than it needs, and is therefore burnt at this part; this is the cause why some of the journals may be crystallized. I have seen thousands of tons of old rails cut up, some of which have been crystallized at one end, and fibrous at the other; some brittle throughout the entire length, and some fibrous; some in one fracture part fibrous and part crystallized, all clearly showing the manner in which the pile had been made up, proving to a demonstration that the rail-maker knew where to put the inferior iron when making the pile for the rail. Tires in like manner present the same appearance as rails; therefore they are not crystallized by vibration.

The grate bar extract is as flimsy as possible, for who would pay Lowmoor price for grate bars? No one. The user wants a cheap wrought iron, and he gets a brittle grate bar, which is continually undergoing expansion and contraction and burning, and these are the causes of grate bars being brittle, and not magnetism. Mr. S. M. Saxby, R. N., some few years ago found that imperfect welds and cracks could be detected by the magnet; this is very ingenious, but he could not make tough iron brittle by it.

The boiler-plate is rather different to the other classes of iron taken. Some people argue that boilers vibrate very much when working, consequently become crystallized. Mr. Carmichael only ventures an opinion on those plates that are exposed to heat. My opinion is this:—The plates, after leaving the manufacturer, and before being put in the boiler, are shaped to a required template, and just in proportion to the circle they are bent to, are the atoms of the plates disturbed by compression on the concave side and elongation on the convex side, sometimes to the extent of fracture. These fractures are so small at times as not to be visible to the naked eye; nevertheless they are there, and ultimately, by the continual expansion and contraction, the invisible becomes visible, and, unless the defective plate is repaired or taken out, may lead to something worse; not because the plate has become crystallized only so far as it has been compressed on the concave side, but because it would not stand bending to the desired form without injury.

There is another very important use iron and steel are put to, well worth our attention, and which I imagine will strengthen me in my conclusions, and that is the wire pit rope. That very flexible and ductile material, which is incessantly being bent backward and forward, continually in a state of tension and vibration, would not stand what is required of it for as many hours as it does months, if the numerous threads of wire comprising the rope were brought so close together as to form one compact bar.

The effects of extreme cold and frost on iron must not be omitted, for only two or

three years ago, on the approach of winter, it was prophesied that the Bessemer rail would be doomed, inasmuch as it would become crystallized or cold short and break. Now, with all due respect to these theories on the causes of crystallization, I wish to affirm that neither vibration nor magnetizing by steam has any such effect on iron, and I will at once give you what I believe to be the causes of crystalline iron, and they are percussion or force of impact, compression or contraction, excessive heat or burning, and last, though not least, the practice of manufacturing finished iron from pig-metal that has been made from iron ores containing phosphorus or silicium.

Take these causes seriatim. Impact does not granulate unless the bar under experiment or accident is nicked with a set, or has some flaw in it to start from, *i. e.*, if the bar or plate is tough to commence with. A bar was shown which would not yield to the force of impact until nicked, but after being slightly cut all round, and receiving a good blow from a sledge hammer, the piece flew off. The bar was afterwards cut on one side, and then struck again with the same hammer, but instead of breaking off short and granular a beautiful fibre showed itself.

Again, in the case of armor plates, the force with which they appear to be struck should crystallize them, if percussion had the same effect under all circumstances. Compression or contraction is somewhat different, but is really a change brought about generally by mechanical agency. I have here a tough fibrous bar bent over in the form of a tuning fork, the outside fibres "give" and are elongated, while the inner fibres become so compressed as to burst and show crystals. Heating a bar hot and hammering it until it is black cold, is simply a bringing of the fibres closer together, causing like results. The threads of iron forming the wire rope are a sort of happy family. If any undue strain comes on one or two of them while passing over the pulley, the others give way and form a cushion to bed them in for the time being; their relation to each other is something like the strands forming a skein of thread. Not so with the fibres of a bar; for they would in a short time become compressed, and that causes crystallization. Thin sheet or iron for tinning would be of little use, if it was not annealed after leaving the rolls; being finished so cold when rolling, the skin is so compressed that on bending it would crack, but on putting the same in a furnace and heating to a red heat, it becomes very ductile, because the atoms of the iron through the effect of heat have become relieved and resumed their normal condition. On asking Mr. Mushet, the metallurgist, some few years ago, to explain the paradox I have here, the answer was, "When you anneal the sheet, if the annealing was long continued, you deprive it of carbon, therefore the annealed piece would contain less carbon than the piece you simply heated and then hardened in water." The thin iron before us was rolled from what is called puddled stock iron, and presuming Mr. Mushet's answer correct, this cold shortness is caused by the iron retaining its carbon; this wants proof by analysis; but this I can prove. The hard or cold short end is contracted, and becomes thinner than the soft end.

Some two years ago Mr. Brockbank, of Manchester, read a paper on the effect of cold and frost on iron, his theory, like many others, being that it caused iron to become brittle, and to corroborate his views he got several gentlemen to test iron for him at a time when the thermometer indicated below 32 deg. Fah. Several gentlemen opposed his theory, and the result of the experiments did not carry with them convincing proofs. A learned professor taking the lead in the opposition, afterwards got a dozen darning needles, and a lot of garden nails (cast iron), a most unsatisfactory material to obtain anything like certain results from; however, he found that the needles took a greater tensile strain at 12 deg. than they did at 55 deg.; the garden nails gave similar results; his general conclusions were that frost does not make either cast or wrought iron or steel brittle. Mr. W. H. Johnson, of Bowdon, tested a No. 4 charcoal rod, and he found that on the test-piece being twisted slowly while surrounded with salt and snow, it stood 19½ twists; the adjacent 6 in. at 40 deg. stood only 15 twists. These and other like experiments tend to prove what I contend for, that iron will bear a greater tensile strain the colder it is, but that its resistance to the force of impact is in ratio weaker. Why is this? for neither of these gentlemen tells us. Because the atoms of the iron are brought closer together by the contracting influence of extreme cold. The specific gravity is greater. It assumes more and more the texture of

steel, which every one knows will not bear a heavy sudden blow without breaking, but try and pull its atoms asunder, *i. e.*, try its tensile properties, and you find it something astonishing.

Sir C. Lyell, in his "Principles of Geology," tells us that fine-grained granite expanded with 1 deg. Fah. at the rate of 4825 ten thousand millionths, and red sandstone 9532 ten thousand millionths, or about twice as much as granite. Professor Joule worked out the mechanical equivalent of heat, proved that a weight of 772 lbs. falling through a space of 1 ft. was able to raise a pound of water 1 deg. Fah. If measurements half so nice as these were made on iron, it would be found that for every degree of heat lost, the iron shrank, and in exact proportion as the atoms are contracted so is its tenacity improved, and its resistance to the force of impact impaired.

Excessive heat or burning will crystallize iron, and cause it to break short when cold. So much was this theory relied upon a few years ago, that it was looked upon as impossible to make a large forging or finish any large mass without it being crystallized, owing to the lengthened time it must be in the furnace before it can be brought to a welding heat. This idea has exploded now, for with careful workmanship and a good fibrous iron to commence with, a tenacious plate has and still is being made in Sheffield for armor plating.

We come now to the primary cause of crystallization, which is the manufacture of finished iron from pig metal that has been produced from ores containing phosphorus and silicium. It is as impossible for us to produce the same quantity of iron from the oolitic or silicious ores as is produced from the hæmatite ores, as it was for the old alchemists to find the stone they dreamed of, which was to convert all base metals into gold. Hence, for the consumer of iron to expect the same article from different districts is a mistake, unless the native ore is disused and others imported, and this adds to the cost.

Nearly all manufacturing districts have their own specialties, cost invariably being in proportion to the quality. And many users of iron finding the cheap article suits their purpose, the manufacturer taxes his skill to avoid this cold short crystalline property. By judiciously mixing the pigs for the puddling process he attains his purpose, and produces for his customer the suitable common crown iron of commerce. This iron eventually becomes so much scrap, and is brought up for reworking into shafts and other large forgings; but the fibres that were developed by the first and second process are lost in this, its third reworking, and the metal becomes crystalline. It is generally expected that by repeated reworkings, all iron improves; this is not the case.

An experiment is recorded in "Metals and their Alloys," where a tough fibrous puddled bar was taken and cut down and piled 5 layers high and rolled into a bar; a test piece was taken from this, the remainder was piled as before, and so continued, until the iron had undergone 12 workings; the result was, it increased in tenacity from a tensile strain of 43,904 lbs. on the puddled bar, to 61,824 lbs. at the sixth working. After this the descent was in a similar ratio to the previous increase, and at the twelfth test it gave again 43,904 lbs. This instance tends to prove that if tough fibrous puddled bar to commence with will not improve only to the sixth working, weak or partly crystallized puddled iron would show depreciation much sooner.

A few words on the utility of iron, and I have done. I ask you to look on that monument of engineering skill that spans the Menai Straits; on that diamond-looking structure at Sydenham, the one stiff and inelegant, the other full of graceful lines, tints, and combinations, and fancy the impetus given to the use of iron by such works.

Think of the wrought guns capable of throwing shot nearly 100 lbs. weight, and the war ships with their sides clothed with plates of iron 14 in. thick to receive them. See the minute indicators on your watch face, and the spider's web-like hair spring that regulates them. And of what use would have been the electric telegraph without the wire rod?—The various experiments and brilliant researches of Galvani, Volta, Arago, Ampiere, Oersted, Faraday, Wheatstone, and others, on electricity and magnetism, coupled with the labors of Cooke and Morse, who brought to a successful issue the means by which a thought may literally, in the words of the poet, "be wafted from Indus to the pole?" When I ponder these things, I am ready to exclaim, "Upon my word, there's nothing like iron."

FRENCH ARTILLERY EXPERIMENTS.

From "Iron."

The results of a second series of very exact experimental investigations made at Bourges, to determine the relative values of long and of short rifle bearings in ordnance have just been made public in France. No programme could have been conceived on more exact scientific principles, to measure the respective effects of fully supporting a projectile along the whole length of its cylindrical body, and of balancing it upon two nearly central points.

To test this point, nine-pound shells carefully turned, were procured from Woolwich Arsenal, with the usual balancing studs in them. After these had been fired at Bourges, from a Woolwich-made gun, the studs were removed and narrow slots were cut into their sides, and they were again fired, but from a Vavasseur ribbed gun, in which they were supported along the whole length of the body. Beyond the differences of rifling, the guns were practically identical, both being tubed with Frith's steel. Not only were the same shells used in both guns, but they were fired on the same days, under the same state of the atmosphere, with similar charges of English made R. L. G. powder of 1.67 density taken from the same barrels. The French officials appear to have taken extraordinary care that no disturbing element should vitiate the experiments for comparative purposes.

The tables published in the "Revue d'Artillerie" show that when the same Woolwich-made shell was supported on long iron rib bearings, the results were at every point superior to its performances in its original state when balanced in unstable equilibrium upon two studs. This superiority increased steadily as the range and elevation advanced, and is shown not only in the initial velocity and the distance attained, but, as we should have expected, in accuracy of flight.

A more crucial test of the relative values of a most important point in rifling for heavy ordnance could not well have been devised, and the scientific accuracy with which the test was applied, makes the tabulated results an invaluable aid to inquiring scientific artillerists. The real gain is not, however, in the elements shown in the tables, but in the endurance both of the gun and of the projectile, which are indicated by the figures; for it is obvious that where all else is equal, low velocity, high powder-pressures, and less accurate flight, are all indications of work wasted within the gun upon its walls and upon those of the projectile. The constant repetition of these extra strains subtract from the endurance, as every projectile issued from a Woolwich balancing gun shows, and as the guns themselves too often testify. At a range of 2,000 metres, the mean gain thus obtained for the same shell under similar conditions, by supporting it on long iron bearings, was 10 min. of elevation, .10 metres less error in range, 1.89 metres less error in direction, .06 metres less height of trajectory, and .15 sec. less time of flight. Whilst at 5,000 metres, the mean gain to the same shell was 1 min. 23 sec. less elevation, 2.90 metres less error in range, 8.25 metres less error in direction, 4.50 metres less height of trajectory, and 1.8 seconds less time of flight.

Thus it will be seen that at every point of accuracy and range, the Woolwich shell, when modified by Messrs. Vavasseur, and the substitution of long bearings for the balancing studs, had greatly the advantage over its former self. Ten different rifled guns appear to have been under trial at Bourges at the same time, and the palm for accuracy was given to the one which fired "les obus de Woolwich modifiés," *i. e.*, with a long iron bearing rib; the original Woolwich studded shell being third on this point; the second place being occupied by the breech-loading "Canon de 4 prussien," and the fourth by the "Canon de 8 francais," a muzzle-loader.

Great importance attaches to these experiments, not so much as it affects field artillery, but as it bears upon the endurance and the performances of heavy ordnance. The heavier the projectile to be fired, the less enduring and the less powerful, relatively, must be the gun, so long as the proportion of the projectile which touches the walls of the gun is nearly the same, whether it be a shot of 100 or of 700 lbs. weight.

A fifty-ton gun will not then have to be devised to do the work of a thirty-five ton gun.

PROPOSED PIERCEMENT OF MONT ST. BERNARD.

From "Iron."

Under the title "Alpine Railways" (see "Iron," Sept. 6th, p. 309), we gave a general sketch of the proposed plan for carrying a railway across Mont St. Bernard; the projectors have since continued the subject at great length, and we shall select from their voluminous documents a few extracts of general interest. The projected line starts from the town of Martigny, which is a station on the Simplon line, starting from Bouveret on the shore of the Lake of Geneva, and which is now advertised for sale by auction by the Swiss authorities, passes by the valley of the Rhone, and reaches the northern flank of Mont Chemin at Charrat; it then passes along the southern flank of the Borgeau, enters the valley of Bagne opposite Sembrancher, and follows the same slope of the mountain as far as Champsec, where it crosses the valley, and turns the northern flank of Mont Larcey, proceeds as far as Sembrancher, and then enters the principal valley of Entremont, and passes along the right side by Chamoille, La Rozière, Reppay, Fontaines-Dessus, Liddes, Alève, and St. Pierre, gains the plain of Prox, where commences the northern end of the tunnel, which debouches at the same altitude in the valley of Menouve. From this latter point the line turns the flank of the hill above Etroubles and St. Oyen, inclining towards St. Remy, and traverses the Combe der Bosses till beyond Chuille, where it traverses the valley of the Bosses, and returns on the right side to Etroubles. From this place it runs nearly parallel to the road from Aosse to St. Remy, and descends by Guiod and Arpouille; it then enters the valley of the Doire; passes above Ponte d'Aviso and Clut, and traversing the river near Villeneuve, arrives at Aoste by the right side of that valley. The total length of the line is nearly 124 kilometres (77 miles English).

The most important features of the plan are the following:—At Borgeau a curved tunnel of 500 metres; beyond Bovernier, two tunnels, one of 100, the other of 300 metres, the mouth of the latter being in face of the old Trappist monastery; between Sembrancher and Vollèges, a tunnel 250 metres long; another of 150 metres, in the side of Mont Larcey; another of 500 metres under Comcure; proceeding on to St. Pierre it enters a tunnel of 150 metres. At an altitude of 1804 metres at the foot of the plain of Prox commences the great tunnel which carries the line into Italian territory; this tunnel is 5,800 metres in length, and lies beneath the Col de Menouve; over the 2,400 metres on the Swiss side the ascent is 0.0048; then follows a level distance of 1,100 metres, and a descent of 2,300 metres on the south side, with an incline of 0.005.

It is proposed to construct this tunnel in four sections, by means of side galleries, so that the work may be completed in three or four years. These working galleries will remain open afterwards for ventilation and other uses. A peculiar feature is that it is proposed to form a station within this tunnel by widening 600 metres of the level, central portion; one of the objects which has led to this singular plan is, that possibly for economy's sake two light trains which had made the ascent separately might be joined together for the descent on the other side. It is also argued that with such an arrangement many tourists would be glad in the summer season to attain the summits of the group of the Grand St. Bernard by the inclined passages already referred to, and at the mouths of which stations for refreshment, and even for lodging, might be established.

The principal works, after quitting the great tunnel, on the Italian side are:—A tunnel below St. Remy of 430 metres; ten kilometres further on a second tunnel 300 metres long, and a third at the Gorge de Cluze 200 metres. The declivity on the Italian side is equal to 0.022. The minimum radius employed for the curves is 30.0 metres, and this is seldom employed. The average inclination of the line is 0.021, and this may possibly be reduced by two or three millimetres.

The soil over and through which the work passes supplies all the necessary materials, so that great cost of transport will be avoided. This is asserted to be the case on both sides; moreover, there exist great masses of anthracite at Liddes, Fontaine-Dessus, and Planardo, for fuel, while the forests afford timber for building purposes.

The total cost of this work is estimated

at 61,510,000f., or £2,460,400, the cost of the great tunnel being set down at 17,000,000f., or more than one-fourth of the sum total.

The connection of Aoste with the Italian lines of railway at Ivrée and Santhia is set down at a further sum of 28,500,000f., making a grand total of 90,000,000.

The projectors devote two long chapters to the question of traffic and consequent profits, but it is not necessary to enter upon this part of the subject, at least at present.

The "Monitore delle Trade Ferrate" says that the Prefect of Turin has made a report on this project to the Provincial Council of Turin, expressing a strong opinion in favor of it, and declaring it to be his opinion that the Government and the Parliament, seeing the consequence of such a line to the Province of Turin, will be inclined to carry it into execution at any cost.

THE CHEMICAL CONSTITUTION OF STEEL.

By ADOLPH OTT.

From "Iron Age."

There is still considerable diversity of opinion among scientific metallurgists regarding the chemical constitution of steel. What elements belong essentially to its composition and which not; in what manner the several substances are combined with each other, and in which form of combination they effect the production of steel; all these and other questions have given rise to lively discussions, especially among French chemists, and are yet to be definitively decided. Chemical analyses, as well as the formation of steel from wrought and pig iron, indicate that iron and carbon must be considered as its most essential ingredients; but, besides, there are found in it in smaller quantities various elements of an electro-positive and electro-negative nature, such as silicon, sulphur, phosphorus, chromium, arsenic, copper, manganese, wolfram, titanium, etc., which partly originate from the pig iron or have been added to improve the quality of the final product. Hence, steel consists as little as pig iron of a pure carbonized iron, but contains also smaller quantities of various other chemical combinations. These secondary ingredients exert either a perceptibly injurious or favorable influence upon its texture and properties of hardness, strength, weldability, elasticity, etc.; but as they vary according to nature and quantities, and are sometimes scarcely to be detected, or are not present at all, without the steel losing its character, as is the case, however, with an increase or decrease of the carbon, we are not entitled to consider these bodies of equal importance as the carburets of iron.

In opposition to these views, Fremy maintains that steel is a compound of carbon, nitrogen and iron, in which carbon as well as nitrogen can be replaced by certain other bodies, so that, as already maintained by Chevreul, there would be many kinds of steel of different compositions, and among them such as contain no carbon. Concerning this hypothesis, however, we do not possess as yet any reliable analytical proofs.

The quantity of carbon necessary to produce steel varies between 0.65 and 2.3 per cent. When containing less than 0.65 per cent the product cannot be hardened any more, and then constitutes wrought iron; while, on the other hand, it becomes pig iron when exceeding 2.3 per cent. carbon. Yet these figures have rather a theoretical than a practical significance, as the amount of carbon of the ordinary kinds of steel varies between narrower limits, viz., between 0.7 and 1.9 per cent. Karsten found in crude and cast steel from 0.9 to 1.9 per cent., in cementation steel never more than 1.75 per cent. According to Mayrhofer, hard crude and cast steel contain 1.84 per cent.; cast and refined steel, too brittle for wires and springs, was found to contain from 1.58 to 1.11 per cent.; elastic cast and refined steel from 1 11 to 0.70 per cent.; soft puddling steel and steely or fine grained iron 0.62 carbon.

The carbon is either chemically bound or separated to a smaller part as graphite. Gurlt considers steel as a mixture of metallic iron and iron containing $\frac{1}{8}$ of carbon (Fe_8C); Tunner, as iron with the compound Fe_4C; Lohage, starting from the supposition that the molecule of carbon is a regular octahedron, considers it probable that by juxtaposition of iron molecules to the corresponding faces, or (according to

the law of formation of the tetrahedron) to the alternate surfaces of the carbon octahedron two different series of iron carburets may be formed. Those with a stable equilibrium of the tetrahedric molecules, Fe_6 C, Fe_{16} C, Fe_{34} C, represent compounds which can be hardened, while those with with unstable equilibrium of the octahedric molecules, Fe, C, Fe_{12} C, $Fe_{\frac{1}{2}}$ C, represent compounds that cannot be hardened.

The hardening of steel and the conversion of gray pig into white pig iron by rapid cooling is supposed to be owing to the fact that the decomposition of the compounds liable to be hardened is prevented.

Mayrhofer established the following chemical formulæ for various brands of steel:

		Fe.	C.
Hard crude and cast steel	Fe_6 C	98.16	1.84
Cast and refined steel, not well applicable to springs and wires, owing to its brittleness	Fe_7 C	98.42	1.58
	Fe_8 C	98.61	1.39
	Fe_9 C	98.77	1.23
	Fe_{10} C	98.89	1.11
	Fe_{11} C	98.99	1.01
Cast and refined steel, well applicable to springs and wires, owing to elasticity	Fe_{12} C	99.06	0.94
	Fe_{13} C	99.14	0.86
	Fe_{14} C	99.20	0.80
	Fe_{15} C	99.25	0.75
	Fe_{16} C	99.30	0.70
	Fe_{17} C	99.34	0.66
Soft puddling steel and steely iron	Fe_{18} C	99.38	0.62

Silicium forms a regular constituent of steel, though occurring only in very small quantities. According to Schafhautl, it is combined with the carbon to carbide of silicium, and every good steel, in order to be liable to be hardened, should contain a certain amount of it. But, if the congruity of silicium and carbon with regard to their crystalline forms, as established by recent researches, is considered, as well as their affinity to the metals, a combination of both elements in steel has little probability, and it must rather be supposed that they replace each other in steel as well as in pig iron. According to all the facts known, it is generally agreed upon that silicium imparts greater hardness and brittleness to steel, diminishing also its strength when present in about 0.05 per cent. and more. The pure compounds of silicium and iron being yet insufficiently known, and since the observations on this subject contradict each other, it is yet doubtful whether silicium is capable of exerting such an influence. I would remark that the compound of silicium and iron prepared by Hahn, with 10, 20 and 31 per cent. silicium, was exceedingly hard and brittle, while Berzelius, on the other hand, mentions that a silicium iron which, on dissolving in muriatic acid, yielded 19 per cent. silicic acid (corresponding to 8 8 per cent. silicium), was soft and could be hammered into thin foliæ.

Sulphur and phosphorus exert on steel essentially the same influence as on wrought iron, producing either red-short or cold-short steel. Eggertz found in good kinds of steel only from 0 to 0.012 per cent. sulphur; of phosphorus from 0.01 to 0.02 per cent. Both contribute to the weldability. Phosphorus imparts to it a fine, brilliant white grain and the property to attain a high polish.

Arsenic, according to Schafhautl, in small quantities, renders steel fine-grained, hard and solid; in larger quantities, red-short. In hammering the best English cast-steel, prepared from Dannemora iron, he obseved sometimes a very strong arsenical smell; he therefore ascribes the superior quality of Swedish iron partly to a certain amount of arsenic iron.

Regarding the presence of nitrogen in steel, on which Fremy lays especial stress, it ought to be stated that the quantities found are so small that it is scarcely possible that it could take an essential part in the constitution of steel. Marchaud, by his investigations, arrives at the conclusion that it is not conclusively proven that cast iron and steel contain nitrogen. Bouis, by conducting dried hydrogen over glowing steel, found as maximum in wootz steel 0.00672 per cent. nitrogen, and Boussingault, by another method, in various specimens of cast steel, 0.007 per cent., 0.042 per cent, and 0.057 per cent.

Copper acts destrimental, and, according to Stengel, as well as Eggertz, a fraction of a few tenths of a per cent. renders steel cold-short. The latter found in Dannemora iron, which is especially valued for the making of steel, only 0.03 per cent., and in various other varieties of steel 0.2 per cent.

Chromium is said to exert an exceedingly valuable influence on steel, but no analyses of such steel are known to me.

Manganese, wolfram, titanium, aluminium, nickel, rhodium, osmium-iridium, platina and silver are also said to improve

steel. There is no doubt that some of these substances, when passing in a remarkable quantity into steel, exert such an influence, but others, which either are only met in traces, or not at all, have either only an indirect purifying effect, or are entirely useless. It is often the case that people ascribe to their presence what has only been a consequence of remelting and of a further working of the steel. Of the last named metals the manganese is the most important.

According to all observations manganiferous ores, especially spathic ores and pig iron produced thereform, are most suitable for the manufacture of steel, and in fining, puddling in the Bessemer process, and in remelting steel, manganiferous fluxes render excellent service. It should be observed, however, that the influence exerted by the manganese is chiefly an indirect one. While, on the one hand, it passes mostly into the slag, on account of its property to be easily oxidized, and often only in traces into the iron itself, it retards, on the other hand, decarbonization, favors essentially the separation of silicium, sulphur, and partly phosphorus, and produces a readily fusing slag, which attacks the walls of the furnaces but little, protects the steel from rapid oxidation, thus rendering the steel more solid and of easier weldability. The latter fact is very important, as steel must be worked at a lower temperature than wrought iron. The most suitable form in which manganese can be used are manganiferous pig iron (spiegeleisen) carbide of manganese, or an alloy of manganese and iron. Added in the oxidized state, as black oxide of manganese, it soon forms a silicate or protoxide of manganese, and acts then, decarbonizing by yielding oxygen.

Wolfram alloys with iron, and passes therefore into steel, as proven by the analyses of Sauerwein, Siewert, and Rammelsberg, who found in the respective kinds an amount of from 0.9 to 7.43 per cent. The Duke of Luynes, as early as 1844, used wolfram for the manufacture of Damascus steel, and called attention to its occurrence in the celebrated blades of Damascus; later (in 1855) it was applied in Austria, England, and France. Wolfram steel distinguishes itself by a very dense texture and a conchoidal silky fracture, by great hardness and strength, and can easily be welded with wrought iron; according to Appelbaum, it requires a greater heat than English cast steel. Rossler found it less suited for mint stamps than Krupp's cast steel, owing to the readiness with which it cracked. However, this steel has not found the general application it was supposed to attain, which may partly be due to its higher price, partly to the difficulty of treating it.

Mushet recommended titanium in order to impart to steel greater hardness and other superior qualities, by adding titaniferous ores in the high furnace, cupola or during puddling. A very suitable iron is thus obtained.

Stoddard and Faraday fused steel with silver, platina, osmium-iridium, rhodium, nickel, aluminum, as formerly Berthion did with chromium. Concerning rhodium steel, it is stated that it possesses extraordinary hardness. Platina steel is said to attain high polish, and nickel steel (meteor steel) is stated to attain the finest damascening. Those investigators ascribe the superior qualities of the Indian wootz steel to a small amount of aluminum, of which Karsten found only doubtful traces and Henry none at all. Gruner and Lan assert, on the contrary, that aluminum acts injuriously, and they call attention to the fact that for the Bessemer process those ores are most suitable which contain the least clay. Of silver only very small quantities pass into the steel (0.2 per cent., according to Faraday and Stoddard). By adding 1.500 silver to cast steel Elsner could not discover any change or improvement, except that produced by remelting. All these often praised varieties of steel have as yet not attained the importance which was ascribed to them.

STORAGE AND DISTRIBUTION OF WATER IN INDIA.

(*Continued from page* 182)

Mr. J. H. Latham said that his personal experience of the district in India embraced by Mr. Gordon's Paper enabled him generally to corroborate the facts stated. The old Hindoo system of village tanks must gradually come to an end, owing to the natural and inevitable silting up of their shallow beds, unless fresh tanks were con-

tinually added, as of old, to supply the place of such as became inefficient for irrigation from this cause. Mr. Latham quoted Col. Playfair, R. E., to show that, in the Deccan and South Mahratta country, the same difficulty existed in the way of this renewal as existed in the Madras Presidency, viz., that village tanks, as a rule, were not paying works. On this account Government could not fairly spend public money upon them, for the benefit of the local villages, nor would private speculators build them. As a fact, charitable persons did not any longer come forward to build them. The old system of village tank irrigation was therefore dwindling away, and any useful system meant to replace it must involve, to a certain extent, novelty. The Madras Government seemed especially to have appreciated this, and had proved the most speculative and successful of the Indian Governments. Permanent irrigation had been secured on the coast by their well-known works at the heads of the river deltas, of which the most important on the Cauvery, Kristna, and Godavery, were calculated to pay from 23 per cent. to 60 per cent.; and by the purchase of the Orissa works from a private company, which were calculated to pay this year 12 per cent. Again, in the Neilgherry hills, there seemed to be no reason why their bold attempt to construct a tank 140 ft. deep by the silting process should not ultimately prove successful. But these plans were not applicable for up-country irrigation, for which the system most advocated, amongst others by Mr. Gordon and Col. Playfair, was that of river channels, combined with reservoirs for storing the water from the monsoon rains. Since the commercial success of such schemes was of primary importance, any information bearing on the actual cost of the works, or on the commercial value of water provided by them, would be interesting. A most important matter affecting the cost of the works was the provision of an adequate escape for surplus water, the quantity of which was, in some schemes now proposed, very large, necessarily delivered at a great height, and requiring costly works. Adopting the formula

$$D = C\, n^{\frac{2}{3}},$$

where D was the quantity of water for which escape was required for a drainage from n square miles of country, and C some constant; then, taking D in cubic yards per hour, in the designs for the Ekrooka tank, near Sholapoor, under construction by the Bombay Government,

$$D = 61{,}523\, n^{\frac{2}{3}}.$$

On the Ganges and Godavery works it was stated that escape would be provided for

$$D = 75{,}000\, n^{\frac{2}{3}};$$

and on the Madras Irrigation and Canal Company's works Mr. Latham was providing escape sufficient for

$$D = 100{,}000\, n^{\frac{2}{3}}.$$

These differences showed how important it still was to have more information on the subject.

The value of the water stored depended primarily upon the area of irrigated crop for which a given quantity of water sufficed. About this great differences also existed. The supply of each cubic yard of water per hour was taken in the Ekrooka scheme to suffice for $\frac{9}{10}$ of an acre for a year's irrigation, and for $1\frac{1}{4}$ acre for crops grown during the wet months. In the Lakh project on the Paihra, as sufficient for $\frac{3}{4}$ acre and $\frac{5}{9}$ acre, respectively, for these crops; and by the Madras Government, as sufficient for $\frac{1}{2}$ an acre only of either crop. The experience of irrigation on the Soonkêsala canal of the Madras Irrigation and Canal Company was too brief to give a definite result, but indicated that, where due care was used to prevent waste, the Bombay practice was nearer the truth than the Madras. That the Madras estimate was too low seemed also indicated by Col. Baird Smith's estimate, that a cubic yard an hour sufficed for $1\frac{1}{3}$ acre of irrigation in India. The water-rate to be charged per acre would, of course, be different for different districts, and was a mere question of the value of produce in the locality. Perhaps Mr. Gordon could give more definite information on the subject of escapes, and on the irrigating power of water in India.

Since the amount of drainage water to be provided for in these reservoirs affected their cost seriously, he would give a few particulars of the rainfall in Southern India during the time he was there. Excepting an extraordinary fall, to which he would refer presently, the greatest depth registered at Kurnool in any one month in the ten years, 1862–71, was 13.77 in., in September, 1862; the greatest depth in one day being 4 in., on the night of the 24th of that month. The only

other occasions on which a total depth of 7 in. fell in a month were in August, 1865, 7.73 in.; and in August, 1868, 7.35 in. Since January, 1868, when the Kurnool Observatory was established, a depth of rain exceeding 2 in. in 24 hours was registered on three occasions, in no case reaching 3 in. But on the exceptional night of the 6th of August, 1870, an extraordinary storm from the south-west occurred, and 12.01 in. of rain fell in twelve hours. At a distance of 13 miles west of Kurnool, the storm was felt in the daytime of the 7th, after rain had almost ceased at Kurnool, and only 7.22 in. fell. At a distance of 30 miles east of Kurnool, an unusually heavy rain occurred during the night of the 6th. This proved that ten years' experience of one place was quite inadequate to determine the frequency of such excessive falls. Two other storms deserved notice; one at Gooty, and the other at Tadamurri, adjacent talooks in the Bellary District, in the autumn of 1864, when a depth of above 8 in. of rain fell in one night. The other was a short storm, which he gauged, at Bŏanassey, on the 72d mile of the canal, when for thirteen minutes rain fell at the rate of 3¾ in. an hour.

The interests of the Canal Company had hitherto required that water should be given to the village cultivators in excess of what they used for cultivation. As to observing an experimental patch of ground, there were insuperable difficulties in the way; for if the patch were isolated the water percolated through the soil and irrigated the surface for yards around, besides passing away through the subsoil. On the other hand, if the patch were surrounded by wet cultivation, the result could not be trusted, so easy was it to transfer water from one field to another surreptitiously; and if the result were trustworthy it would not give the average requirements for cultivation. The only proper observation would be to see how much water per hour per acre was actually used—when it was served out without waste; and that he had not been able to ascertain.

Colonel J. T. Smith said, as far as he could make out the Table on which the results given in the Paper were founded, there was one important element neglected, viz., that half the value of the produce was taken by the Government in assessment. The results of commercial speculation depended upon, first, what was paid for an article, and, secondly, upon what it could be sold for. To begin with the sale of the water, he had not been able to make out how it was deduced that £1 1s. per acre irrigated was the value; but the value so calculated was not important, for when discussing a commercial speculation connected with a concession from the Government, the Company was bound to accept the terms of the concession, and the Government concession of the privilege of storing water in South India was connected with a condition to sell it at the rate of 12s. per acre irrigated. Therefore he conceived the real commercial result ought to be based upon the 12s. per acre, and it would mislead the public if they were induced to believe that a return of 46 per cent. was to be obtained by selling the water at a guinea when there was actually no power to do so. He, therefore, concluded that the results ought to be based upon 12s. per acre.*

He now came to the cost of the water. He thought the Author had acted with great impartiality in the statements of cost, yet he could not agree with the results. The calculation was based upon an average reservoir, able to store water at the rate of 4,250 cubic yards per £1. That was an imaginary reservoir; but a description was more particularly given of one reservoir which was proposed to be immediately restored, viz, the Mudduk Masoor tank. He would say with regard to that, as well as with regard to the statement of past profit derived from Government irrigation works, that it was one thing to construct a work, and another thing to take a work already constructed, and simply out of order. If he brought forward a project for taking up a large number of houses out of repair, and showed that by putting them into good order he could make 23 per cent. by it, the scheme would appear very attractive; but the question would arise—who would give so valuable a concession? The Government, as possessors of these old tanks, had little to do to put them in order, and consequently made very large profits. It was stated that the Mudduk Masoor reservoir was about 40 square miles in superficial area when full; and that it con-

* The Author guarded his statements by the express provision that the actual values were to be realized, but there was no such qualification in the second conclusion submitted to the meeting; and although it is quite possible that an increase in the water-rate might hereafter be allowed, yet such an increase ought not to be assumed in stating the present value of a mercantile speculation.—J. T. S.

tained 1,400,000,000 cubic yards of water. It was proposed to lower the dam from 90 or 108 ft. height to about 70 ft., and then the area would be about 24 square miles. The Author, by experiments on the spot, found that an average monsoon rainfall yielded about 668,000,000 cubic yards of water; consequently he proposed to provide a reservoir which would contain a little short of that, viz., 644,000,000 cubic yards, which would be the capacity of the Masoor reservoir with a dam 70 ft. high. Upon this it might be observed that unless the monsoons were of great uniformity, it was not sufficient to provide reservoirs equal to the average expected; they ought to be capable of holding the maximum as well as the minimum rainfall. The question, therefore, arose, whether the district was one in which the seasons were uniform, or fluctuating.

He had the following reason to believe the seasons were extremely fluctuating. It so happened that the Company who proposed to construct this reservoir suggested another in the same neighborhood, called the Maury tank. The Chief Engineer sent home a report, founded upon observations, the result of which showed that there was abundance of water to fill the tank, and it was resolved to make application to the Government for it. But the Government hesitated to grant the concession, on the ground, partly, that the supply of water was insignificant compared with what was estimated, and partly because it was not more than the country required, and they therefore finally resolved to keep it for the use of the inhabitants. He had also been informed privately, but on good authority, that a similar hesitation was now felt as to granting the concession of the Masoor tank, and for the same reasons, namely, that the supply of water was much less than was supposed, and not more than was required for existing demands.

Now he did not attribute these different estimates of the probable rainfall to errors of observation on the part of the various officers who made them, but to the fact that they were made at different times, and that the fall of rain in the district was very uncertain. Hence if the parties constructing such reservoirs made their calculations on the ground of storing the average monsoon rainfall, they must have a larger tank than the average monsoon rainfall would fill. Calculating without this would tell in one of two ways. Either the tank would cost more from building it larger, or there would be less water on the average than was anticipated; and on those grounds he thought some deductions ought to be made from the Author's estimate of the value of the produce of these tanks.

The next point was the evaporation from the tank. The specimen or representative tank was supposed to contain 4,250 cubic yards for every £1 sterling laid out upon it; which, allowing for interest on the money during construction, was calculated to yield 340 cubic yards per rupee; but it was necessary to modify this calculation, because it was one thing to have the water in the tank, and another to have it on the land.

Reverting to the Mudduk Masoor tank of 24 square miles area, and 640,000,000 cubic yards capacity, the Author had estimated the evaporation during four months from that tank while it was being emptied, and his calculations had been made upon proper data, which corresponded with experiments carried out by order of the Madras Government, whereby it was deduced that in the middle of the tank the evaporation was about one-third of an inch per day, or 10 in. per month. This result was, however, subject to a deduction of one-half, inasmuch as there was a reduction of surface from 24 square miles at the beginning of the discharge to a greatly diminished surface at the end. That through the evaporation down to 20 in. in the four months, over a surface of 24 square miles, and amounted to 40,000,000 cubic yards, or $6\frac{2}{3}$ per cent. of the 640,000,000 cubic yards which the Masoor tank was to hold. Now, $6\frac{2}{3}$ per cent. during the four months was equal to 20 per cent. during the year. For it must be noted that, although it was quite sufficient to calculate the evaporation from the surface of the reservoir during the months of discharge only, if the object was, from a given quntity at the beginning of the discharge, to determine the quantity which left the reservoir, yet the case was different when, with a given average monsoon rainfall, it was intended to ascertain the loss by evaporation during the time of its collection in the reservoir, its preservation there, and also its discharge. For this purpose the evaporation for the whole year must be taken into account, at an average of half the surface during collection and discharge,

and during the remainder as for the whole surface. Hence the loss for the whole year would be 20 per cent. without reckoning the full rate during the interval of repose.* And here he would mention that when the experiments were made on which the rule of the irrigation department was founded, viz., that one-third of an inch per day was evaporated from the middle of a large tank, the gentleman who had charge of the experiments reported at the end of the season that $\frac{5}{8}$ of what had left the tank left by evaporation, and only $\frac{3}{8}$ had gone on the land; that was, 62½ per cent. was evaporated, and only 37½ per cent. had gone on to the land; the field referred to being in the immediate vicinity of the tank, so that there could not have been a length of more than from 10 to 20 miles of irrigation channels.

The next question to be considered was that the water let out of the Masoor tank did not irrigate the fields immediately, but went down the bed of a river for 200 miles. He believed the bed was in some places rocky, and in others sandy and absorbent. Thus the water was in motion for 200 miles before it reached the irrigation canal, and an allowance must be made for evaporation and absorption. After reaching the head sluices the water had, on the average, 100 miles of main canal to traverse, and that canal was very leaky. There was a great deal of loss by leakage, not, however, owing to any fault of the Engineers, for they had done their duty perfectly. But it was leaky, partly owing to the extreme badness of the soil, and partly because, owing to financial considerations, it was thought advisable to let it remain as it was for the present, as it would have required a considerable expenditure of money to have made those banks tight; and it was thought better to postpone that expense till the water was more valuable than it would be for the first few years. In addition to the distance already traversed, there were between 300 and 400 miles of distributing channels finished, which might possibly be increased to 500 or 600 miles before they were all completed† He would prefer that others should judge what was the proper allowance to be made for the losses referred to—first, by evaporation in the reservoir; secondly, in the bed of the river; thirdly, by leakage and evaporation in the main canal; and fourthly in the distributing channels.

In estimating a scheme of this kind, and calculating the financial results, it was proper to be on the safe side. The Government decided that 2 cubic yards per hour for each acre was necessary; but he observed that Mr. Gordon had calculated 5,000 cubic yards per acre only. He thought it should be 6,000 cubic yards. The average time of cultivation was about 130 days, and 2 cubic yards per hour per acre for 130 days was more than 6,000 cubic yards. Again, the mere evaporation alone, from the surface, at the rate he had stated, namely ⅓ in. per day, would come to 8,000 cubic yards for the six months, and more than 5,800 cubic yards for 130 days; and hence, taking also into consideration absorption and other losses, he thought 6,000 cubic yards was the least that ought to be allowed for.

To recapitulate his remarks respecting the formation of the tanks, Mr. Gordon's estimate, after allowing for interest during construction, was 340 cubic yards per rupee. Now he had given reasons for thinking there ought to be an increase in that estimate, or, in other words, a diminution in the number of cubic yards stored per rupee. If, for instance, the Masoor dam were built of the full size, to secure the whole monsoon rainfall in every year, it would cost double the money estimated by the Author, and instead of 960 cubic yards per rupee, there would only be 480 cubic yards. In the same way, in regard to the specimen tank, instead of 340 cubic yards per rupee, there ought to be much less, if the whole rainfall were calculated. As he wished to take a most moderate view of the case, he would only strike off the 40 cubic yards from the 340, leaving the estimate at 300 cubic yards per rupee. But this did not represent the quantity actually put on the field; and, in his opinion, if the Madras Irrigation and Canal Company got one half of the water upon the fields, they would do very well. In that case they would have 150 cubic yards per rupee on the field, and the 6,000 cubic yards required for the irrigation of each acre would cost Rs. 40, for which they would receive Rs. 6 return. Now Rs. 6 for every Rs. 40 amounted to

*Owing to a strange clerical error, the Author had omitted to make the deduction of 12 per cent. which he allowed, so that the £1 9s. 5d. per acre was based upon the supposition that every drop of water in the tank was spread upon the land. —J. T. S.

†It was not hereby intended that the water must traverse these 300 or 400 miles; the distance run would of course vary with the situation, from a few chains possibly, to a number of miles.—J. T. S.

15 per cent.; and if 3 per cent. were allowed for repairs, superintendence, and management, it left 12 per cent. to be divided between the proprietors of the old and new works; and he believed this to be a fair estimate. He had no wish to exaggerate; but he thought it was right to sift an important question like this, and if he had made any mistake, the Chief Engineer of the Company would no doubt correct him.

There was one more point he must advert to—a point of expenditure, viz., Who was to insure these large works against accident after completion? He thought Government would, on general principles, be disinclined to grant concessions for reservoirs, if they believed the parties were likely to realize 46 per cent. from them. They might still more hesitate to give a concession unless they had security that, in case of failure, there would be some funds to meet the loss. To give an idea of the magnitude of these works, he might state that the proposed reservoirs were four hundred times the size of the Bradford reservoir, near Sheffield, the failure of which caused so much disaster and loss of life and property some years ago. It was true the country was not densely populated, but there were towns and villages, and a good many inhabitants, within reach of danger. Therefore it might be supposed the Government would require security, in connection with works of the magnitude referred to, and the provision of some party responsible for, and able to make good, any damage.

Mr. Russel Aitken said, the quantity of water required to irrigate a certain area depended very much upon the nature of the soil, as well as the crops to be raised. In the case of sandy soils a large quantity was wasted, as the water soaked into the ground, thereby raising the spring-level of the country. The value of water depended very much upon the nature of the rainfall. In the Concan in Bombay and other places, where the monsoon rainfall was most abundant, a supply for one crop could always be depended upon, but this was not the case in other parts of India. Then, as regarded the crops raised, in some parts the produce could not be disposed of without great cost for land carriage. The distance from a market made an enormous difference in the value of water for irrigation purposes. Those who embarked in irrigation projects were apt to consider that, as soon as the water was provided, it would be taken up immediately; but that was often not the case. In the first place, there must be population to cultivate the ground; then the cultivators must acquire capital to buy bullocks, build houses, and obtain agricultural implements. Therefore the expectation of an immediate return from these works was, he thought, a great mistake. The returns from the Ganges canal varied from 1 per cent. up to 2½ per cent., after paying working cost, which, even in a fully developed canal, amounted to 25 per cent. of the total revenue, and it was only in 1868-9 that it paid 7¼ per cent., and that was an exceptional year. In the case of the large returns reported of some of the Government works, they had been constructed under very favorable circumstances, so far as regarded the natural facilities afforded by the ground, and also by the comparatively low rates of labor which then prevailed.

Large canals in the deltas of Madras had been constructed for about Rs 7,000 per mile, and that was a very cheap rate when compared with some new canals there, the construction of which had cost at least Rs. 70,000 per mile. Thus, returns which now paid 30, 40, or 50 per cent. on the smaller cost, would give but 3, 4, or 5 per cent. on the larger expenditure; so that the first cost of the works produced a material effect upon the returns of profits.

The actual value of water in any canal varied so much that no definite conclusions could be given. On the Ganges and the Eastern Jumna canals, the annual revenue for a discharge of one cubic foot of water per second was as under:

	Ganges Canal. Rupees.		Eastern Jumna Canal. Rupees.
1866–67	374	....	422
1867–68	390	....	519
1868–69	525	....	653

The water-rate was only about Rs. 2 per acre per crop; whereas in Madras and Bombay it was much higher.

In Bombay he had made a number of observations fruitlessly to find the quantity of water required to cultivate land. Waste, as in waterworks in England, was the chief difficulty. As to the different values of water, he might give one instance to show how it varied. In calculating the value of water from a proposed reservoir about 50 miles from the town of Bombay, he came to the conclusion that a cubic foot per second,

for eight months of the year, was worth Rs. 715 per annum for field cultivation, while in the Island of Bombay water was worth, for market gardens, Rs. 8,200 per cubic foot per second, or nearly twelve times as much. It depended upon the crops cultivated, the nearness of the market, and whether there was population to take up the water supplied.

Although irrigation works in India did not, as a general rule, offer a field for profitable speculative investment, yet there could be no doubt as to the duty of the Government of India in this matter. Not only did the Government get large revenues from the water-rates, but canals contributed to the revenue in many indirect ways. In 1868-9 there would have been a famine in North-western India but for the Ganges canal and other canals. The Government, being the proprietors of the land, derived revenues from the land-tax, as well as the water-rates; and if there had been no crops to gather, the Government would have lost the land-tax, whereas they had the benefit of both land-tax and water-rates. In many places, where it would not pay a private company to construct works for irrigation purposes, it paid the Government to do so. In Poonah, a large garrison town, the Government were constructing irrigation works; but he doubted whether they would give any considerable return upon the outlay, though, when the effects of irrigation in reducing the price of forage, and other benefits resulting from a supply of water, were considered, there was no doubt whatever of the necessity for those works being undertaken.

One other point he would mention, viz., the difficulty there was in following this discussion owing to the varying quantities that were spoken of. In Madras the calculations were at per cubic yard per hour; in the north-west the rates were taken at per cubic foot per second; while in Bombay he had been in the habit of calculating in million gallons. It was very desirable that the measurement of water in irrigation works should be reduced uniformly to the cubic metre per minute, which would be better than when several varying standards were employed.

Mr. J. Aird observed that from the drawings there appeared to be a total absence of any puddle gutter—a work which was accustomed to be regarded as an important element in the construction of large reservoir banks. Experience showed that when a leak occurred in a reservoir bank, it was difficult to stop it in the absence of a puddle gutter, or some protecting material of that sort. He would be glad to hear what means had been taken to protect the slopes of these reservoirs. If they were of the enormous area described, with the varying climate, heavy rains, and strong winds, they must be exposed at times to much wash, and without adequate protection upon the slopes there might be considerable danger.

Mr. A. Jacob stated that there was a large waste of water in the beds of the rivers. He had gauged many rivers in India, and found that the amount of water discharged at the head was nearly the same as at the outfall. The tributary streams discharging into the main channel were numerous, and it was evident that much of the water must be lost by evaporation. There was an old saying in India, that irrigation works on rivers increased the discharge of the river; or, in other words, that there was more water got out of the river than it appeared to discharge above the works. Keeping this in view, it was surprising to see the important results produced by placing dams across rivers at intervals of 5 or 6 miles asunder.

He dissented, to some extent, from the views expressed by the author as to the superiority of high embankments. No doubt a reservoir of great depth gave a less degree of evaporation, *cæteris paribus*, than a shallow one. But shallow tanks were easier of construction by native labor, and for a given quantity of earthwork the tanks were cheaper, because the material was at hand; and when the work was performed by basket labor, everything, as regarded cost, depended on the distance from which suitable material had to be carried, which in large banks was sometimes very great. At the present time the Government fixed 12s. as the basis on which the financial return was to be calculated. Seven or eight years ago, a uniform rate of Rs. 1 per acre was fixed by Government; and though he had matured many projects, none of them could be calculated to pay on such a low basis. It seemed very small, when it was notorious that the natives were prepared to take water at Rs. 15 to 20 per acre irrigated. Unless the Government would charge at a fairly remunerative rate, as the natives would do themselves, neither Government

nor private companies could expect to get a reasonable return for their money.

Mr. Hemans, Vice-President, remarked that 5,000 cubic yards turned into cubic metres or tons, represented 3,750 tons, equal to a depth of 37½ in. of water per acre. That, at the rate of 12s. per acre, would be at the extremely low price of $\frac{3}{100}$ of 1d. per ton. He did not understand how a crop of rice could absorb such a large amount of water as 3,750 tons per acre. Colonel Smith said it should be 6,000 cubic yards. It was customary in England to irrigate with diluted sewage at the rate of 5,000 tons per acre; but from that land 60 or 70 tons per acre per annum of the rankest and richest grass crops were taken, in a series of crops of 5 or 6 tons each. He wanted to know how that quantity of water could be absorbed or necessary, in addition to the natural rainfall, and whether the quantity stated was applied to one crop or two crops of rice per annum; and further, how it was possible the profits stated could result from the price of $\frac{3}{100}$ of 1d. per ton of water.

Mr. H. Conybeare had given some attention to the impounding of water, having constructed for the water supply of Bombay a reservoir covering 1,400 acres, and in parts upwards of 80 ft. in depth, which he believed was one of the largest modern works of this description. No one could have witnessed the almost magical results of irrigation in tropical and semi-tropical climates, in converting a desert into a garden, without feeling a strong desire to be able to make out a good case in favor of the extension of irrigation as a commercial undertaking. It was therefore with great regret that he had come to the conclusion, that no such case had as yet been made out, at least as regarded tank irrigation. Obviously the most important element in the calculation was the cost at which the water could be stored; but, unfortunately, there was still great uncertainty, and widely differing opinions, as to the number of cubic yards of water that could, under average circumstances, be impounded for a rupee. The author of the paper had assumed the quantity to be 700 cubic yards in favorable cases, and 340 cubic yards in unfavorable cases. The cost of the earthwork in the dam was taken at only 3d. per cubic yard, but it was doubtful whether such work could be executed under 6d. per yard. Moreover, these calculations appeared to be entirely based on estimates; whereas on a point of this practical nature, and of such great importance, it was only safe to rely on the basis of accomplished facts. To be satisfied on such a matter there should be official records showing the actual particulars of cost, and also the contoured plans of a number of reservoirs actually executed, by which the storage capacity of each might be computed, together with such detailed drawings of the dams, etc., as would allow of the quantities of the work involved in impounding the water being accurately checked; such data, in fact, as had been afforded, in respect to the irrigating tanks in Ajmeer and Mairwara, by Colonel Dixon's work. A book had been published by Sir A. Cotton, in which reference was made to the enormous returns that works of irrigation were calculated to yield in India as commercial investments, and in which this work of Colonel Dixon's was grievously misquoted. Sir A. Cotton stated (page 123) that under ordinary circumstances storage reservoirs could be constructed at as low a rate as R. 1 (2 shillings) for each 2,000 cubic yards of water stored, and under favorable circumstances, to store thrice the amount; and he stated (page 254) that in the one-hundred and twelve irrigating reservoirs constructed by Colonel Dixon in Ajmeer, in Rajpootana, the average cost of water was one rupee for each 8,000 cubic yards of water stored.

Colonel Dixon's work for impounding water in Rajpootana, of which Sir A. Cotton spoke so highly, afforded the most economical examples as yet on record of works of this description. The Government of India were of opinion that "it would have been impossible, in almost any part of India, or under any other superintendence than Major Dixon's, to have constructed such works." Accordingly the Court of Directors requested that Colonel Dixon would prepare a report of what he had effected in Mairwara, and a detailed account of the improvements recently made in Ajmeer, accompanied by scientific plans, sections, and drawings, of his more important works, founded on actual survey and measurement. They further ordered that, when prepared, such report and illustrations should be printed and circulated at the expense of the Government of India, for the guidance of officers engaged in similar operations. The report so called for was subsequently published in a quarto

volume, containing scientific descriptions and illustrations of eight of Colonel Dixon's principal storage reservoirs, together with a general description of the remainder.

A comparison between the rates at which Sir A. Cotton so positively calculated on impounding water, and at which he stated that Colonel Dixon had impounded water, with those actually obtained in the most economical works of Colonel Dixon's extensive practice in Rajpootana, would afford no unfair criterion for testing the general accuracy of Sir A. Cotton's figures and calculations. It would appear, on instituting such comparison, that Sir A. Cotton had calculated the cost of storing water about ten times too low; and that the final cipher ought in most cases to be abated from his numerical statements. For it was to be presumed that the eight examples of reservoirs which Colonel Dixon had selected for detailed illustration, out of a total of one hundred and twelve, would be considerably more than average specimens; as it was, indeed, known they were, from the particulars afforded by his tables regarding his less important and unillustrated works. Yet, on analyzing the elements of the eight model works so selected, it appeared the most economical result obtained was 688 cubic yards of water per Rupee, the lowest only 102 cubic yards per Rupee, and that the average number of cubic yards of water stored for each Rupee, expended merely in labor and materials, was only 284 cubic yards per Rupee, and for four of the eight model examples, was under 200 cubic yards per Rupee. Whereas Sir A. Cotton stated (p. 123): "I calculate that water can be stored at 2,000 cubic yards per Rupee (2 shillings), an estimate which is the result of long experience among the tanks of the Carnatic. Without any remarkable advantage in the site, a bund may be made almost anywhere at this rate; but in many situations where the form of the ground favors it, thrice this amount may be stored for a Rupee (2 shillings)." He also estimated the average results of Colonel Dixon's practice in Ajmeer at 8,000 cubic yards per Rupee. Moreover Colonel Dixon's tanks were constructed at exceptionally low rates. The masonry in mortar was only 1s. 6d. per cubic yard, and the earthwork, "well beaten and rammed," was executed at the low rate of $1\frac{5}{8}$d. per cubic yard. Now, Engineers of Indian experience would know that earthworks of that sort could not be sublet in India at the present time at less than four times the rate that Colonel Dixon paid for his work. Sir A. Cotton remarked in his book, that if these reservoirs had been larger (the eight selected for illustration in this work were much larger than the average of such works in India), the water could have been more economically stored. That was true theoretically; but, on the other hand, the sites where enormously large quantities of water could be economically stored were very exceptional, and where they did occur they usually involved exceptional sources of expense, which detracted materially from their theoretical economy. In the case of the large reservoir which he had made at Bombay, covering 1,400 acres, and 80 ft. deep, with every attention to economy, he was only able to store 162 cubic yards per Rupee, and that work was done by contract. Therefore he was afraid no case had been made out for the extension of tank irrigation, as a commercial speculation, in India. The results were so uncertain; there were so many circumstances to cause variation in the profits; and, as he had shown, the actual cost of impounding water was so much greater than it was usually stated to be. But there were a very large number of ancient tanks throughout India and Ceylon, that had become breached for want of a waste weir, the repair of which could not fail to prove remunerative as a commercial investment. Even in cases where irrigation would not answer as a commercial investment to outsiders, it would still be worth the while of the Government to undertake such works; because in most parts of India Government stood in the position of being the universal landlord, and the amount of indirect profit they would get in saving the remissions of land-tax in seasons of drought would make to them the difference between a loss and a profit. Moreover, were a large proportion to the land in any district under irrigation, famine and its incidental calamities and losses would be rendered impossible. There was, therefore, no question regarding the enormous importance to the Government of the extension of irrigation.

He was not acquainted with any dam in India, constructed by natives, which had a puddle wall; but the bank was usually an enormous mass of earthwork, and being built up with basket labor, and being thus deposited in very thin layers, by means of

the constant trampling of the men, women, and children, employed in carrying the baskets, the whole structure was rendered almost as compact and impervious as puddle. Some of the great reservoir dams in Central India, like that of the Saugur lake, consisted of two parallel walls enormously massive, and built at so considerable a distance apart, that in the interval (filled in with well-packed earth) there were often forest trees and hamlets; thus the fort, and a portion of the city of Saugur were built on the dam of the Saugur lake. He knew of no native reservoir with a bye-wash, and even a waste weir was often absent.

Mr. F. C. Danvers said he had endeavored to ascertain, from published reports, the commercial value of water in India, and had been struck with the variation of returns from canal and other irrigation works. He found, from the reports annually issued by the Government, that the sum of £5,712,000 had been spent upon irrigation works in Madras, the Punjab, and the North-western Provinces, the returns upon which were as follows: Madras, 29.41 per cent.; Punjab, 7.01 per cent.; and the North west Provinces, 5.06 per cent.; yielding an average return, on the whole, of 10.5 per cent.

In Madras, of the 32 principal irrigation works, eighteen showed a balance of income over expenditure, and fourteen yielded no direct net return, but showed a deficit. Of the remunerative works he might mention the following:

	Cost.	Net Revenue.	Return.
	£.	£.	Per cent.
Lower Coleroon....	11,647	39,442	Over 338
Upper Coleroon....	23,986	42,561	177
Vallaur Anicut	8,215	10,442	127
Godavery Anicut..	432,886	175,116	40.4
Pennair	59,050	6,470	Nearly 11
Kristna Anicut....	271,720	20,747	7.6

In the Punjab the direct income gave 7.01 per cent.; but if the indirect income was added, the return was equal to 12.52 per cent. upon the capital outlay for irrigation works. The indirect revenue, in the shape of enhanced land tax, arising from the beneficial effects of irrigation upon the land, was calculated at 12 annas, or 1s. 6d. per acre. Of the six large irrigation works in the Punjab, only two returned a profit from direct revenue, viz., the Western Jumna and the Baree Doab; but, including indirect profits, all but the Upper Sutlej were profitable. The Western Jumna canal showed a direct net profit of 35.82 per cent.; and the Baree Doab of only 2.86 per cent. The former was one of the oldest of the Mogul canals, and irrigated 496,543 acres; the latter, a work of modern times, irrigated 233,927 acres.

It had been stated that, in the North-west Provinces, the net returns were 5.06 per cent. on the entire capital expended; but a portion of the expenditure was upon works not yet opened. With that deduction the return was equal to 5.13 per cent., and it was estimated that if a fair addition was made for increase of land revenue, the returns would be equal to upwards of 8 per cent. Of the seven large canal systems in the North-west Provinces only three returned a net profit, viz., the Ganges, the Eastern Jumna, and the Dhoon canals. The other four worked at a loss, so far as direct revenue returns were concerned. The Ganges canal showed great fluctuations in the returns obtained respectively in seasons of drought and good monsoon rain. In the year 1868–9 the net profit was 7 per cent., and in the following year only 4 per cent., which was mainly owing to the difference of rainfall. The Eastern Jumna canal returned a profit of 23.33 per cent., and the Dhoon of only 2.58 per cent.

With reference to the value of water, Colonel Dickens, in his Report on the Soane canal, laid it down that, "Excepting in the rich land near the Ganges and a few other favored spots, the unirrigated crops of wheat and barley are very scanty, and are said to produce only 256 to 640 lbs. per acre; and those irrigated once or twice yield only from 512 to 1,024 lbs. per acre; irrigated three times, the crop is said to yield from 896 to 1,280 lbs. per acre; but the people told me if they could irrigate four times, using abundance of water, they would get from 1,280 to 1,920 lbs. per acre." To irrigate thoroughly, Colonel Dickens considered 17,600 cubic feet of water per acre were necessary for the season. The average assumed in drawing out the projects for the Baree Doab and the Ganges canals, derived from data afforded by the Jumna canals, was that each cubic foot of discharge per second was capable of actually irrigating 218 acres. In the Soane canal project, Colonel Dickens estimated

the effective duty of water at a somewhat higher rate.

The actual results obtained from some of the principal canals in Northern India were as follows: Area irrigated per cubic foot per second of water actually employed in irrigation, after deducting volumes escaping at terminals—

	Ganges.	E. Jumna.	W. Jumna.	Baree Doab.
Acres	186.03	268	240 ...	154.91

He was unable to obtain definite information as to the extent irrigated by a cubic foot of water per second per acre in the Madras Presidency; but he had seen a calculation in which the rate laid down was 2 cubic yards per hour per acre, which was equivalent to 200 acres for each cubic foot of water per second, and that agreed nearly with the estimate for the canals of the North-west Provinces. In older works, as had already been shown, the value obtained was higher, viz., 240 to 268 acres; while the Ganges and the Baree Doab yielded the less return of 186 and 154 acres respectively.

The water-rates realized per cubic foot of discharge per second were—Ganges, Rs. 378; Eastern Jumna, Rs. 538; Western Jumna, Rs. 499; Baree Doab, Rs. 127.9; and the water-rate per acre irrigated was nearly the same in each case, viz., Ganges, Rs. 2.25; Eastern Jumna, Rs. 2.32; Western Jumna, Rs. 2.41; and Baree Doab, Rs 2.35. This was for the autumn and spring crops. The rate varied slightly according to the crop; thus, on the Ganges canal, for the autumn crop it was Rs. 2.57 per acre; and for the spring crop, Rs. 2.00 per acre; the mean being Rs. 2.25.

In conclusion, he would draw attention to recent numbers of "Professional Papers on Indian Engineering," in which the semi-official correspondence addressed to the private secretary to the Viceroy, by Major Corbett, B. S. C., on the question of, "Is Irrigation necessary in Upper India?" was published by desire of the Viceroy. It was contended that superior cultivation to what now exists was alone necessary; that at present the ground was only scratched a few inches deep with the native plough; and below that there was a hard crust which prevented the water filtering through; and that if that was broken up, and the cultivation carried deeper, there would not be the same necessity for irrigation, because evaporation from the land would not take place to so great an extent.

Major J. Browne, R. E., stated that in Upper India tanks were not generally employed, as the slope of the ground was so great that it would require dams of great height to hold in even a moderate supply of water. In some parts, the foot of the hills afforded an opportunity for building tanks; but they were on a small scale, and generally ended by drying up and being taken up for cultivation. Mr. Gordon had mentioned that the proper method of defending the masonry in falls, against the violence of the water going over them, was to provide water cushions. No doubt these were beneficial; but another method was employed in the canals of Upper India, which he believed was more efficient; and that was to place on the crest of the dams stout timber gratings, composed of baulks about 6 in. by 6 in., and about 2 or 3 in. apart, and slightly slanting upwards. The effect of this grating was to cause the water going over the crest of the weir to fall in thin films, and consequently with less destructive effect; the velocity of the water was also thereby materially checked. Besides, in Upper India destruction was caused by the drift logs that floated down the canals in floods; and these great logs, 20 or 30 ft. long, taking headers over the falls, smashed everything before them; but the grating protected the masonry from this cause of demolition. These gratings had been used for many years by Colonel Dyas, and they answered as a most efficient protection to the masonry of the falls.

Mr. Latham had mentioned, with regard to the discharge to be provided for in catchment basins, that the formula was represented by—The discharge, equal to a constant quantity, multiplied by the drainage area, raised to the power of two-thirds. That was Colonel Dickens' formula, with one slight difference, viz., that the drainage area was raised to the power of three-fourths instead of two-thirds. This did not make much difference in a small drainage area, but it did in large catchment basins.

At the foot of the Himalayas the rainfall was very great, and exceeded anything that had been mentioned; coming up to 4, 4½, and 5 in. per hour. In such districts the formula which gave the best result, taking the discharge in cubic feet per second, and the drainage area in square miles, was—Discharge equal to 1,200, multiplied by the drainage area raised to the power of $\frac{3}{4}$. He believed the circumstances in Madras were

somewhat different; but in Upper India, and particularly in the Punjab, it appeared to him that canal irrigation was largely supplied to districts where it was not so much required, and denied to districts where it was most required. The rainfall in the Punjab varied inversely as the distance from the great Himalayan chain which ran to the north, and on which the rainfall varied irom 80 to 210 in. In the Sub-Himalayas it varied from 40 to 60 in.; at 120 miles from the hills it was not more than 30 or 40 in.; going to 250 or 300 miles from the hills, the rainfall came down as low as 3 or 4 in.; while in Scinde it was scarcely more than 2 or 3 in.

The depth at which water was found in wells followed the same rule, varying as the distance from the mountains. Where the rainfall was not under 30 in., and the depth of the wells did not exceed 30 ft., canal irrigation, though advisable, was not absolutely necessary. The great difficulty was to get sufficient water to irrigate those districts where canal irrigation was alone possible. Most of the water that came down the Baree Doab canal, and a great portion of that which came down the Ganges canal, was taken up by those districts where the wells were not more than 30 ft. deep; and the result was that the villagers had allowed their wells to choke up, and had become entirely dependent upon the canals.

The moral of this was, that in the great projects that had now to be taken in hand, well irrigation should not be entirely lost sight of. There was no water to spare; and it seemed to him economy had not been observed, where canals were employed in districts where irrigation could be practised, even to a small extent, by wells. No doubt canals must sometimes be taken through districts where well-irrigation was possible; but the canal ought to go through such districts not as an irrigation canal, but merely as a channel conveying water down to the lower districts, where the rainfall was so small that irrigation was absolutely necessary. He was aware that there was a great deal to be said against well-irrigation, and that it cost so many pounds, shillings, and pence, to hoist so many cubic feet of water from a given depth. As a purely mechanical arrangement, he did not put well-irrigation in competition with canal-irrigation; but in a commercial and social point of view there was a great deal to be said in favor of well-irrigation. Except perhaps the Civil Courts, there was no greater cause of discontent in India than canal-irrigation. Villagers who used their own wells were not exposed to be bullied by canal understrappers, who might threaten to cut off the water, and compel their attendance in Civil Courts; and they were free from official restrictions in the distribution of the water. Then, again, as a commercial speculation, canal companies must necessarily lay out a great sum, which could not return any interest at first starting, and probably for a very long time; whereas money laid out in wells, if it paid at all, would pay very quickly; as a well could be started, and be in full operation, if not more than 30 ft. deep, within a month after it was begun. A company for well-irrigation could feel its way without risk; whereas a canal company must lay out money freely, and, getting no return for a long time, might find itself, perhaps after twenty years, in the receipt of 1 per cent. dividend per annum. As to hoisting water from the well, in many parts of India, particularly below the hills, the wind was for the most part very steady during the morning and evening, and a good deal could be done by windmills. Then, again, by irrigating by wells the waste was avoided which always resulted more or less from canal-irrigation, and spoilt the crops by souring and oversoaking the soil. He had always understood from such cultivators as he had spoken to, that crops raised from well water were of a better quality than those raised from canal water. He could not say whether it was due to the higher temperature of the well water, or to any chemical difference in the water itself, but canal-raised were, he believed, generally inferior to well-raised crops.

He did not wish it to be supposed that he at all undervalued the vast benefits of canals. They were indispensable, no doubt, where irrigation could not be obtained by other means; but in the ambitious projects of the Government and of private companies, he thought they had too much lost sight of the question of well-irrigation; and it had apparently been forgotten that there was possibly as much water below as above the surface. It was admitted, that in Upper India, there was barely enough water on the surface to irrigate those districts where well-irrigation could not be employed. Therefore, for every acre of land irrigated

by canals which might have been irrigated by wells, an equal acreage in another part of the province was condemned to perpetual barrenness; and this would be the case whenever canal water was supplied to districts where well-irrigation was possible.

In a social and commercial point of view irrigation by wells had many advantages, although as a mechanical arrangement he did not wish to defend it. It seemed to him that, with the improved means of communication in India, well-irrigation was a means of preventing, to a great extent, and at a very early period, the recurrence of those famines which might come at any moment, and which might occur for years before those more ambitious projects, which he did not, however, undervalue, had been well started, and had begun to do any good to the country.

Mr. G. Gordon, in reply upon the discussion, said Mr. Latham had inquired what allowance had been made for the discharge of storm-water from the reservoirs, and as to the calculation of it in reference to maximum rainfalls in India. He had used no formulæ. He had ascertained what the maximum flood discharge of the rivers had been during a period of 15 or 20 years, and that was exceeded by a recorded flood by perhaps nearly twice as much. It could not be accurately measured, because there were no reliable marks to go by; and that extraordinary flood was calculated as the measure of the maximum discharge. He did not think any general formula could be used for all places; a formula founded on observed rainfalls and floods in one district would be useful for other districts similarly circumstanced, where the rivers had not been gauged; but in no case could observations with regard to climatic conditions be dispensed with. He agreed with Mr. Latham, that the question of the quantity of water per acre necessary for efficient irrigation was a difficult one, and had never been, and probably could not be, definitively settled; because different soils, as well as different crops, required a greater or less supply of water, according to the peculiar circumstances of the case. Rice required more water than any other crop. The result of the experiments made by the Madras Government was to fix the quantity at 2 cubic yards per hour per acre, or 66⅔ acres per cubic foot per second. That corresponded to 5,000 cubic yards per acre per crop, and was calculated to be the quantity required for rice; while more valuable crops, which would bear a higher water rate than rice, took less water to irrigate them. Colonel Smith objected to the quantity of 5,000 cubic yards per acre, and thought that at least 6,000 cubic yards should be allowed; but a few years ago Colonel Smith, in reporting on a project of his, had assumed 3,600 cubic yards as the quantity required for the second crop, which was the one a reservoir had to supply. He mentioned this to show the quantity had not been agreed upon or calculated with certainty for different districts; but in estimating, it was necessary to take some standard; and that of the Madras Government, of two cubic yards per hour per acre, was what he had adopted.

Speaking of the cost of the water, Colonel Smith was mistaken in saying he had taken an imaginary average reservoir. It was a reservoir carefully surveyed and estimated, and was, out of several so estimated, the one least favorably constructed for the storage of water. It was not the favorable one proposed to be constructed by the Madras Irrigation Company—favorable with reference to the number of cubic yards of water per rupee stored. The case of the proposed restoration of the Mudduk tank was an extremely favorable one, and he had never met with any other instance where so much water was stored at so small an expense. But Colonel Smith objected to that estimate, because, he said, the supply was uncertain, and he compared it with the Maury Convai tank, of which the supply had been proved to be uncertain. Colonel Smith seemed to think these tanks were in the same neighborhood, whereas they were nearly 100 miles apart, and the characters of the two districts were totally different. The one was on the inside slope of the Western Ghats, and the other on the table-land of Mysore, where the rainfall was very precarious. They were no more comparable than were the Rivington Pike District and the east coast of England. The capacity of the tank was not quite equal to the maximum discharge of the river. No doubt, in that instance, it would be better if the tank were capable of containing rather more than the average discharge; but that could be effected, not at double the cost, as Colonel Smith supposed, but by the usual expedient of putting in planking on the waste weir to a height of 5 feet. The rivers rising in the Ghats fluctuated much less than those in the table-land. The

usual way was to put planks between posts on the waste weir, and to take them down in case of heavy floods.

The evaporation had been calculated from observations taken in the neighborhood, the monthly evaporation being multiplied into the mean area exposed every month. The tank was just filled at the end of the monsoon season, and the small surplus of water now discharged by the weir after that was not taken into the calculation, although it was sufficient to make up for a great part of the loss by evaporation. The tank was full only at the end of the season; then the water was gradually drawn off, and the tank was supposed to be emptied in four months. For each of these months he had estimated the quantity carried off by evaporation over the exposed area of the tank, and the total amounted to 5 per cent., instead of 6¾ per cent., as Colonel Smith calculated by a rougher method.* Multiplying that by the four months, Colonel Smith calculated the total evaporation to be 20 per cent. of the contents of the tank. That would bring up the evaporation to 120 inches per annum, an amount never yet registered to his knowledge. Colonel Smith had mentioned a tank in which ⅝ths of the water was wasted by evaporation, and only ⅜ths was put upon the land; but that tank was a very shallow one. If the tank had a depth of water of only 60 or 70 in., with an evaporation of 30 in., more than half would pass away by evaporation; but the case was very different in a tank 60 or 70 ft. deep. Even in the dry season there was always a small stream running into the tank, which was filled by the monsoon supply alone. The loss from the canal which Colonel Smith referred to was not much, and the water quickly deposited a layer of fine mud on the bottom and sides, as happened in filtering beds. A case was known where a channel in sandy ground had to be widened, and it had been so well lined with natural puddle, that the enlargement was carried on without stopping the supply; the excavation close to the old channel was quite dry even below the level of its bed. The evaporation of the water of the canal was not ascertained, because it was included in the 2 cubic yards per hour per acre; in which, too, the evaporation in the passage of the water from the reservoir down the river to the canal was also included. The bed of the river was rocky, with here and there layers of sand left by the floods; lower down, about Kurnool, there was more sand. Even after the streams ceased running, the drainage of the country into the river, which was the main drain of a very large district, was more than sufficient to make up for the loss by evaporation. It had been gauged in the hot weather, and the discharge was found to be less in the upper than in the lower part; in 1868 it was only one-eighth. This differed from Mr. Jacob's experience in the Bombay Presidency, where he found that though a good deal of water flowed in, the evaporation made up for it, and the river discharge at the lower end was more than it was at the upper end. The objection that the reservoir did not hold the whole supply did not apply to the other reservoirs estimated for, which were more favorably situated; because there the difficulty was not how to fill the reservoirs, but how to get rid of the surplus water. The largest reservoirs he found took little more than half the monsoon supply of the river; and then the water required to be embanked to prevent it running over a water-shed into another river. The difficulty was to get sites where the floods could be impounded. The Mudduk Masoor tank was capable of impounding the whole flood water. He could not accept Colonel Smith's conclusions, that only half the water stored was used on the fields. Colonel Smith gave no figures in support of that conclusion; and he believed 15 per cent. would be the full amount of waste, assuming the Government rate of supply of 2 cubic yards of water per hour per acre in the main canal.

Mr. Aitken had stated that canals which cost only Rs. 7,000 per mile, gave returns of from 40 to 60 per cent., and that, therefore, others costing Rs. 70,000 would yield only 4 to 6 per cent.; but the quantity of water carried must be reckoned, not the cost per mile. He admitted that the different measures used, viz., the cubic yard per hour in Madras, and the cubic foot per second in Bengal, and in some cases gallons, were very inconvenient; but the difficulty would not be remedied by the introduction of a fourth measure, the cubic metre. He thought the reckoning by cubic feet per second was the most handy.

From time immemorial it had been the

* The months March and April, when the evaporation was greatest, were those when the area of water in the tank was least.

custom to dispense with puddle in native works, and in the parts of India he was best acquainted with, there was no clay to make puddle with; in fact, there was a district 250 miles long and 100 miles broad where no stiff clay was to be found. There was at first a little leakage in a new bank, but it soon got puddled by the deposit from the muddy water, the banks became impervious, and this was effected by the silt existing in the river. In some cases the slope of the reservoir banks was protected by large stones built in the form of steps, and in others they were laid on the flatter slopes. Breaches often occurred in small tanks; they were generally repaired by forming a ring dam in front, and sometimes the bank was cut to relieve the pressure of the water. That was done, when it was possible to do it, where the bank was on rocky ground, so as to cause as little damage as possible.

A great part of the water was evaporated after it was turned on the fields. The evaporation in places exposed to the hot winds was $\frac{1}{3}$ in. per day, and a crop of rice was under water about a hundred days; so that about 33 in. would pass away by evaporation, which left only 5 or 6 in. to be disposed of by infiltration and drainage. The evaporation was perhaps reduced in the last months of the crop, by the water being sheltered by the grain, and, he believed, might amount to 30 in. altogether.

In experiments made by Colonel Meadows Taylor on the wells of the Deccan, it was found that 6,000 cubic yards was the quantity per acre used for the two crops of the year. The first crop consisted of turmeric, chillies, ginger, plantains, and other valuable garden produce; the second crop was wheat or cereals. For those two crops rather less than 6,000 cubic yards of water per acre were sufficient, and in the use of wells there was very little water wasted, as the water was raised at a cost to the ryots of Rs. 27½ per acre, exclusive of interest upon the cost of the wells

The reservoir mentioned by Mr. Conybeare was a comparatively small one, and he agreed that a small quantity of water could not be stored economically in India for the purposes of rice irrigation.

As to the revenue to be derived from irrigation works, if the Government fixed the rate so low that it was not remunerative, it was likely to give them a bad name. It was said they were not constructed because they were not remunerative; but they were not so only because the Government would not allow a charge which the people were ready to pay.

He thought the plan adopted by Colonel Dyas for breaking the force of the water in the falls of the Baree Doab canals an admirable one. The effect of the gratings was to break up the falling water and distribute it over a larger area, but he thought the plan was less applicable to weirs in rivers, to which the remarks about water cushions in the Paper referred, as all the length that could be got for clear overfall was needed, and the introduction of gratings would require a greater length, or else the level of the water must be inconveniently raised. He thought them excellent for canal falls, and they seemed to have answered their purpose perfectly. The well-irrigation, which seemed to please the people in the part of India described by Major Browne, would never be extensively practised in the South. In the Deccan 4½, and in Bellary 3 acres, were the most one well would irrigate; the water was slightly brackish generally, and the cost of raising it by the cheapest method, if animal power was employed, was too high—55s. per acre in the Deccan, probably 80s. in Bellary, and 60s. at the experimental farm at Sydapett, Madras.

Mr. A. A. West supplied, through the Secretary, a table of the evaporation at Bombay, during the dry season, from a surface of 100 sq. in. of water in a cistern, open to the air, but shaded from sunshine:

	Days.	Inches.	Inch. Average.
1814, October	31	4.80	.155 a day.
" November	30	4.60	.153 "
" December	31	4 45	.143 "
1815, January	31	4 15	.134 "
" February	28	3 85	.137 "
" March	31	4 65	.155 "
" April	30	5 55	.185 "
" May	31	5 30	.174 "
Total	243	37 35	.154 "

The rains of 1814 ended on the 14th of October. Those of 1815 began on the 5th of June. The greatest evaporation in a day was 0.20 in. in the middle of April and latter part of May. The least was 0.12 in. in December and early in January.

During the month of May the thermometer varied from 90 deg. to 102 deg. Fahr. in the open air shaded from the sun; and from 87 deg. to 90 deg. in the house from 8 A. M. to 11 P. M.

The evaporation at Bombay during the rainy season, under the same conditions as the preceding, was: (See Table A.)

The rains of 1815 began on the 5th of June, and ended on the 16th of October. The evaporation in August was high; it was 2.35 in. in 1814, and 2.45 in. in 1816. The greatest evaporation in a day was 0.18 in. in clear weather in July and August, and 0.19 in. in October. On wet days it was 0.10 in. The least was 0.05 in. during continual rains in June and July.

TABLE A.

	Days.	Inches.	Inch Average.
1815, June	30	3 05	.102 a day.
" July.....	31	3 10	.100 "
" August	31	4.60	.148 "
" September....	30	4.45	.148 "
Total.....	122	15 20	.124 "

THE PRODUCTION OF TRAFFIC AND THE TRANSPORTATION OF FREIGHT AND PASSENGERS.

BY MARTIN CORYELL, C. E.

From "Transactions of American Society of Civil Engineers."

Early history and the ruins of ancient civilization attest that Asia and a part of Africa were first densely populated; that agriculture, commerce, and the arts were developed in high degree, and that the carriage and exchange of products of the soil, materials for building, munitions of war, and the objects of commerce then were necessary to a luxurious people. Among the remains of that age, there is nothing to show the use of modern substitutes for manual labor or beasts of burden, in performing the work of inland transportation.

China and Egypt had canals at an early day, and used their rivers similarly for travel and transportation. Greece and Rome employed ships in commerce and for war, constructed canals, opened roads, and erected bridges, the remains of which are still to be seen.

Coming down to modern times, the first canal in France—between the rivers Loire and Seine, 34½ miles long—was begun in 1605, and completed 37 years afterward; in England, the first—the Bridgewater Canal—was begun in 1758. Coaches were introduced about 1605, prohibited in 1635, and in 1770 only 1,000 were registered in the whole kingdom. With coaches, turnpikes, or roads on which tolls were levied, came into use; about 1790, Telford and McAdam began improving them, and in 1819 Parliament appointed a committee to examine into their condition.

In this country—soon after the Revolutionary war, as agriculture, manufactures and commerce began to thrive, the people, and particularly those on the seaboard, saw the need of a ready means whereby the products of the soil and the forest could be exchanged for commodities brought over the seas or made up in town and city. The experience of older countries was consulted, and turnpikes were determined on, not only as meeting a want much felt, but as a profitable investment for surplus funds; charters therefore were granted by State authority, and soon roads were built, connecting growing cities with fertile agricultural regions or thriving manufacturing centres.

Pennsylvania was the first State to have regularly a graded and stoned turnpike, which was chartered in 1792 and finished in two years; it was from Philadelphia to Lancaster, 62 miles long, and cost $465,000, or $7,500 per mile. So beneficial were its effects upon trade, and the country through which it passed, that it was extended to Pittsburgh, the most westerly town at that period, 303 miles distant, with ascents not exceeding 3¾ degrees, and passengers were carried in post-coaches from there to Philadelphia in 60 hours. When the road was completed, the traffic was not sufficient to pay dividends and for repairs, but in a few years it so increased that double loads were carried in vehicles drawn by 4, 6, or 8 horses, and consequently the tires of the wheels of the "Conestoga wagons" were

widened from 1½ to 5 or more inches. The results were that, under the effects of frost, rain, and the heavy traffic, turnpikes became expensive and unprofitable; and people, in good weather, would travel over a parallel road to avoid paying toll. Soon they were unpopular and condemned by the community generally, and most unjustly; for, until over-burdened by the quantity and weight of traffic, they served well their purpose; thereby cities and towns were built up, the lands through which they passed were increased in value five-fold, and the general enhancement of taxable property was ten times the original cost of the turnpikes. Now that they are relieved from heavy and ruinous loads, they are, if well made and kept, as useful and profitable as in their early career.

Canals were next in this country to relieve commerce, by an exchange of productions, and in their construction New York was first, with that ever-enduring monument of enterprise, the Erie Canal, which was the model, and furnished the engineers and contractors for many others throughout the various States. The history of canals is similar to that of turnpikes; the investments made in them were, in a great measure, lost to the original projectors and owners; generally they were located along rivers, subject to injury by extraordinary freshets, and extended so far towards the river's source that the traffic necessarily done in seven months only of the whole year was made unprofitable by the amount of lockage, scarcity of water, and effects of frost.

When the early canals were completed, their capacity for transportation was so far in advance of the needs of the country, that they largely absorbed the traffic of turnpikes without, for years, earning enough to defray expenses and pay dividends; but as it was with turnpikes, wherever canals were located, manufactures, trade and travel greatly increased, cities and towns were built up, and the adjacent country became prosperous and wealthy; consequently, in time the canals were overcrowded with the trade they had reared and were unable to accommodate, and soon, therefore, they too were, in degree, condemned and neglected.

The railroad next claimed public attention for the carriage of freight and passengers, and when the locomotive was made its special adjunct by George Stephenson, it took rank and character which led to a success that completely revolutionized transportation and its various interests. Like the turnpike and canal, the railroad in early years was subject to trials of poverty, want of trade and depression of stock, but now it is triumphant, fearing only that the telegraph may take from it the postal and money business of the country as effectually as it did from its slower predecessors.

At first, railroads were only intended for portages between navigable waters; it was generally conceded that they would for many years be all-sufficient when the rivers and lakes of the great West were reached, and it was deemed useless and impracticable to think of proceeding further without transshipment. The productions of the South and West so accumulated that the labor and delay at points of transshipment became a serious cause of waste and cost, which, added to the cost of transportation, tended to exclude these commodities from Eastern markets.

The scheme of bridging the Ohio, which floats a vast and increasing commerce in fleets of boats of every style, was violently opposed by the Federal Government and the people at large, in Congress and the Courts, to prevent an attempt characterized as chimerical. The history of the Wheeling bridge attests what a grand success it was; it does, and may it ever stand, a pioneer monument of commercial enterprise and engineering skill, proving that traffic by rail need not destroy or greatly obstruct traffic by water. When a few more bridges, as the St. Louis and East River, and a few more tunnels, as the Detroit and Hoosac Mountain, are completed, the chief problems in railroad construction will be solved, and the question "Will it pay?" can be answered.

One of the earliest and boldest innovations of the railroad upon water navigation was when a line was projected and built along the Hudson river. Our worthy and Honorary Member, Mr. John B. Jervis, as engineer, demonstrated that the Hudson River Railroad was not only practicable to construct, but profitable to operate. Most people thought it a wild scheme thus to contend for the trade of a free and noble river like the Hudson, with gorgeous steamboats, moving 16 miles per hour, numbers of sailing vessels and acres of floating timber; all without the least tax for tolls, repairs or management, while transportation by rail-

road would be subject to the large expenses of construction and operation. The result is before us: now, two double track railroads, well equipped and prosperous, share the traffic with the river—a third is projected, and there is trade enough for all; not to mention the vast consequent improvement of property and increase in values, along these lines, and as far as their connections extend.

Mr. Asa Whitney, formerly of New York, now of Philadelphia, conceived the "audacious project" of constructing a railroad, thousands of miles in length, from ocean to ocean, through a wild and mountainous region, not only for traffic but to build up cities, develop the country, and divert trade from what had been always considered its natural channel, the sea, across an uninhabited continent. Heretofore commerce had directed the means of transportation; now the railroad was to win commerce from nations where before it had scarcely existed. In May, 1849, Mr. Whitney published a pamphlet entitled "A project for a railroad to the Pacific," in which were set forth many of the details of the grand scheme as it was afterwards accomplished. The road has been built for years, and yet his name is rarely mentioned in connection with this, one of the greatest undertakings of modern times. Now the North Pacific and the Southern Pacific Railroads are in course of construction; other lines, through British America and Mexico, are projected; all to compete for the traffic of Asia and the Pacific Islands, and to aid in peopling the large uninhabited areas of this continent.

In contrast to these broad plans for commercial and national progress, attention is called, without comment, to the following extract from a letter of Hon. Jefferson Davis, Secretary of War, dated February 24th, 1857: "Under the appropriation of $30,000, made on the 3d of March, 1855, 75 camels have been imported. The limited trial which has been made, has fully realized my expectations, and has increased my confidence in the success of the experiment."

Cheap, or as they are commonly termed, "narrow gauge" railroads, with light rails and well-constructed machinery, will, in time, be substituted for common roads, as feeders and distributers of main lines. In populous manufacturing or in agricultural districts, where the traffic is insufficient for more expensive lines, these may take it at profitable rates until roads of greater capacity are required.

Although railroads and their machinery, as a means of transportation, seem to be nearly perfected, the studies and services of the engineer are not soon to be dispensed with. A brief consideration of subjects now more or less prominent show rather that the field of his labors will in the future be more extended and diversified; a few of these subjects I will mention.

Marsh and swamp lands are to be reclaimed by embankments, ditching and subsoil drainage; rice, cranberries, cotton and other similar crops are to be irrigated; lands are to be cultivated and their products gathered by the aid of steam machinery; forests are to be preserved from the ravages of fire, and extended over barren lands, to keep up and increase the supply of fuel and timber, and to equalize the amount of rainfall.

The water in our streams is to be stored up in time of plenty, for domestic and sanitary purposes, to extinguish fires, irrigate lands, furnish power, and to maintain the navigation of canals and rivers. Rivers are to be improved and secured; basins, docks, and wharfs for shipping, elevators for grain, and warehouses for merchandise, are to be constructed. Canals are to be reconstructed, an abundance of water for increased traffic provided, and the locks extended to take in without delay, at one time, a steam tug and the boats she may have in tow.

Railroads are to connect the large cities of this continent, located, equipped, and operated to maintain a speed of 100 miles per hour with safety and certainty. Superior and intelligent management must reduce the rates of freight, so that the products of the soil and the mine, in regions widely separated, may be exchanged without loss, and at a fair remuneration to the producer.

Safe and permanent buildings, for commercial purposes, with foundations "strong and deep," are to be erected capable of resisting fire, floods, and the severities of our climate, fitted with machinery for hoisting and moving goods or grain, well ventilated and thoroughly adapted to the secure preservation of the property contained, without danger from loss.

One feature more or less relating to transportation, connected with the mining and marketing of coal, and in a less degree with the handling of ores and the manufacture

of iron, has long exercised those managing these interests. The trade demand for coal in special sizes is irregular and spasmodic, whereas its production and preparation by suitable machinery is uniform, day by day, and in such quantities that accumulation of any particular size soon stops the entire work. In early spring there is a large demand for "lump" and "steamboat" coal, and but little for "prepared" or "special" sizes, which hence have for months to be forced upon the market at ruinous prices, or wasted on the "culm" or dirt pile, to make room and keep the "breakers" clear. In the fall and winter this is reversed; orders then come in so fast for "prepared" sizes, that extra machinery is employed to crush the best coal and thus supply the demand at an enormous expense and waste, most of which in the end has to be borne by the consumer.

This loss and more could be saved if proper arrangements were made to transport daily to market direct, the entire production of the mines, and there have storing grounds and the necessary appliances to prepare the material as required for immediate use, so that what is wasted at the mines could be utilized as cheap and useful fuel. More than one-half of the coal in our mines is wasted there or in preparation for market; the mountains of coal dirt which disfigure our coal districts should cause regret and shame to the capitalist, engineer, and miner. All the items that enter into this waste can be taken up and adjusted, so that in the anthracite coal trade alone, 50 cents per ton, or $10,000,000 annually may be saved.

The present equipment of railroads—particularly of those specially devoted to the coal trade—is in design and build adapted to but a limited variety of traffic, and consequently cars are returned empty, or when rolling stock is in great demand, stand for months upon a siding, depreciating in value more rapidly than when used. By the system of car construction, and the want of adaptation to required uses, toll rates are necessarily increased; and, in consequence of this and other abuses, it will only pay to send the choicest and most valuable products to their natural market or place of consumption.

All these things are within the province of the civil engineer; but no one man can singly effect their improvement. It is the aim and end of this Society to include within its membership those who not only can lay foundations under rivers and seas, tunnel beneath lakes and through mountains, span navigable waters, and unite the extremities of a continent, but who, because of their integrity and experience, possess the confidence of those who supply the means, as well as of those who do the work of these undertakings. With such in co-operation, our profession can always perform whatever trade, commerce, or the good of our common country may require of it.

Mr. McAlpine—On the 8th of May, at the invitation of the Chamber of Commerce of New York, I addressed the merchants of the city on the subject of transportation,* a very broad field. Certain results of investigation made in preparing that address may perhaps surprise you, as they did me.

Corn sometimes is burned for fuel in the West, simply for the want of transportation. I compared the cereal production of the United States for the last three or four years with that of the civilized world elsewhere. The cereal production of the world, in bushels, is a little short of 5,000,000,000; the United States last year produced 1,500,000,000, of which ten Western States, including Kentucky, produced 1,000,000,000, or $\frac{1}{5}$ of that of the world. I became satisfied that 2,000,000 tons of the production of the great West fail to reach the Atlantic markets, worth, including transportation, at least $200,000,000; in other words—and because every dollar's worth of production sent to the seaboard buys another dollar's worth that is returned to the country—the Atlantic markets have lost $400,000,000, and the people of the West one-half that sum.

Referring to the question of difference between communication by rail and by water, I ascertained that the four trunk railways from the East to the West—the New York Central, the Erie, the Pennsylvania, and the Baltimore and Ohio, carried only one-fourth of all that came East; the remainder came over the Erie and Welland canals. In regard to the cost, the products of the country may be carried 1,000 miles by water almost as cheaply as 100 miles by land. Freights from Albany to New York are the same as from New York to Liverpool. From New York to San Francisco the rates per ton are—by the Pacific

* Address by Hon. William J. McAlpine, before the Chamber of Commerce, at the Cooper Union

railroad, about 3,000 miles, from $60 to $100; by the Isthmus of Panama, about 7,000 miles, $20, and around Cape Horn, about 16,000 miles, but $12.

Railroads and canals are not antagonistic, they are parts of the same system and both indispensable. Railroads are required for the carriage of passengers, valuable parcels and perishable articles; but in this country they cannot be substituted for water conveyance. Who expects to see in his day the Erie Canal abandoned? The best talent and skill has been engaged in the management of railroads, which is not the case to any considerable degree with canals. To-day, steam has not yet been successfully tried on the Erie Canal, and boats are still towed by horses, as they were by the Ptolemies in Egypt 3,000 years ago. The ocean steamers have not yet taken the place of sailing vessels. Thirty-five or forty years ago the locomotive was imperfect, and its success was uncertain; it has been completed within a few years, comparatively, and now is the greatest machine of the age; the combined achievement of the superior intellects applied to its development.

Prof. Greene—I have given the subject of steam canal navigation some attention for the past two years, having been connected with a commission in New York, appointed to test the various plans proposed for introducing steam upon the Erie Canal. My estimates show that the cost, including all expenses, of moving boats by horse-power in the canal and on the Hudson river is about five mills per ton per mile. The cost of transportation by rail depends upon the grade, expense of construction and many other circumstances. On the principal trunk lines the cost at present seems to be about 1¼ cents per ton per mile.

I have made estimates to ascertain how far this might be reduced on lines devoted exclusively to the transportation of freight, where trains were moved without interruption or being laid up on side-tracks, and found that the minimum cost, including all items of expenditure, would be about 7¼ mills per ton per mile. The experiments made with steam upon the canals during the last two years show a reduction of cost, as compared with horse-power, of from 22 to 25 per cent.—based upon transportation from Buffalo to New York, by way of the Erie Canal and Hudson river. If steamers were used exclusively, this saving might possibly reach 50 per cent.

I have considered the different ways of towing. By the ordinary canal-boat, carrying its own machinery with 200 tons of freight, and towing two other boats of the same size carrying from 225 to 235 tons, the cost seems to be about the same as by that where the machinery is applied directly to each boat; the objection is that boats towed at the speed of three miles per hour become unmanageable, and captains will not take the consequent risk; even at 2½ miles per hour there is danger of injury by collision.

Where a tug-boat tows two or three loaded boats the cost is decidedly greater than if each boat carried its own machinery. The reasons are obvious: the tug-boat would at first cost as much as three or four ordinary canal boats. I cannot quote the figures, and will only suggest a line of investigation, whereby any person interested in this subject may arrive at a conclusion. Another reason is found in the application of the power. The size of the boat is determined by the size of the load. A single boat may carry and use as much propelling power as is required by those making up the tow; but there is always a certain loss from slip, which increases rapidly with the number of boats towed and the power expended, so that when three or four boats are towed, the loss may be 50, 60, and even 80 per cent.—that is, the power utilized may be only 20 per cent. instead of 50 to 70 per cent. as it should be.

Another objection to moving boats in tow is that much time is lost in lockage. A single boat may pass a lock in about five minutes; where there are two boats, one being towed after the other, the first will go through as quickly as a single one, but the second boat, having no power, will be twice as long, and the time thus lost will similarly increase for every additional boat towed, so that when there are four or five boats, a large part of the time required to make the trip will be spent at the locks, where the boatmen are idle, the power is useless, the fires are burning and the interest account is going on. Then again, a towed boat, having no power of its own, will not last as long as a boat having its own power, for the reason that it cannot avoid collisions.

I have given attention to the Belgian system, and would say, that while it is per-

haps successful in Belgium, it could not be so here. It consists of a wire cable, laid in the bottom of the canal, which works over a clip dam operated by machinery. I understand that the Belgian canals, for the most part, are very straight and have few locks; on the contrary, American canals have many sharp curves and excessive lockage, both of which are serious obstacles to the successful introduction of such a system.

Mr. Shinn—I do not know that I can add any very precise information to that already possessed by the Convention on this subject, but I will make a few statements which, while they differ in some respects from those of gentlemen who precede me, may open a field for investigation. This subject of transportation is the question of the hour. During the past six months it has largely entered into the debates of Congress, occupied the time of State Legislatures, and been discussed in the meetings of farmers' granges, and by other assemblages. There is a demand to know whether transportation cannot be performed better and cheaper. Investigation has naturally caused discussion, and a great variety of views are put forth, most of which do not proceed from a scientific or professional source, or present facts which can be relied on to determine the real state of the question.

It has been said in this Convention that in this country railroads have received the attention of the best engineering minds—not in the broad sense, that to construct and maintain them the ablest engineers have in some capacity assisted, but that in railway management they have largely taken part. I think this is an error; surely those who are prominent in managing the principal railways are not noted as skilful engineers, but rather as successful manipulators of Legislatures, operators on Wall street, speculators who get up corners in stock and increase or depreciate nominal values. These are the men who control railroads—not by virtue of their ability as practical managers, but because they own stock, or possess the confidence of those who do. No men in this country are less likely to become either manipulators of Legislatures or victims of Credit Mobilier schemes than those of our profession; prominent engineers do not get up schemes of that kind either to run railroads or to build them. On the other hand, men who control and operate our railroads are not investigating the scientific basis on which the economy of transportation depends, or employing others to do so, and as a consequence the wildest notions prevail on the subject.

It is asserted by those who have looked into the matter somewhat, that it cost $1\frac{1}{2}$ cents per ton per mile to transport freight by rail. I am prepared to say that on the more important railroads of this country freight was transported at a profit last year for $\frac{1}{2}$ cent per ton per mile, and therefore the actual cost must have been less. The rate in 1872 for the transportation of fourth-class freight from Chicago to New York, was about 40 cents per 100 lbs., of which 5 cents was expended at New York to get it across the river and deliver it to vessels in the harbor; leaving 35 cents per 100 lbs., or $7.00 per ton received for transportation over 900 to 960 miles of railway. The roads which carried freight at this rate never made more money than last year, hence this business was not done at a loss, as it was a large proportion of the traffic. From this it is evident that the maximum cost was 7 mills per ton per mile; that, of course, was upon freight moved in full trains of loaded cars, and under circumstances most favorable to the present railway management.

Instead of the economy of railway transportation receiving the attention of the best engineering talent in the country, it seems to me that such talent has been studiously avoided, and rigorously excluded from any controlling voice in the management. Within my own knowledge, roads for years have been run with an equipment which was not more than two-thirds adequate to do the business pressing upon them. In this case the railway was a machine capable of doing twice or three times the business it was doing, but its equipment was insufficient to employ it more than one-third or one-half the time. In one instance, after frequent respresentations of this fact to the managers, an unusual pressure of business having convinced them that more equipment was needed, they suddenly increased it without making any corresponding extension of terminal facilities or side tracks, and then the machine was disproportioned the other way. There was nearly, perhaps quite enough equipment for the time, but sufficient terminal facilities to dispose of the traffic as fast as it arrived, and side tracks to allow the

trains to pass without delay, were lacking, and so the business of the road was crippled by blockades at the terminus, and along the line. Where 400 cars per day should have been handled, not more than 100 got through; thus illustrating, in not an encouraging manner, the kind of engineering talent applied to some of our best railroads.

The capacity of railroads to do business, compared with canals, should not be judged by the amount done upon the four existing trunk lines, none of which, so far as I know, are managed upon a scientific basis. They are not generally controlled by men who value engineers, or employ them to do anything more than to locate the road, and, perhaps, construct some of the works. Hence these lines have been slow to develop the resources of the country, procure sufficient equipment, acquire necessary terminal facilities and adequate means at tidewater to dispose of what freight could be brought there. For instance, the Pennsylvania Railroad, which has the reputation of being one of the best managed railroads in the country, has been unable to get rid of more than 60 cars of grain, in bulk, per day, without being blocked up. The number of cars is not limited until they are really blocked, and then the blockade is transferred back from Jersey City to Philadelphia, and from Philadelphia to Pittsburgh, until every yard on the line from Jersey City to Chicago is full. The need of increased facilities at Jersey City has been for some time very evident, but the stockholders of the Camden and Amboy Railroad declined to spend $4,000,000 there to get rid of freight for the Pennsylvania Railroad, which they hauled only 90 miles. While the latter road would be greatly benefited by an expenditure of this sum in filling up docks, increasing depot facilities and building elevators, it manifestly would make no return to them, and therefore they would not appropriate it. This particular instance of a single defect in railway management will in due time be remedied.

It is true that a vast amount of agricultural products is not taken to the seaboard, but without doubt a much larger amount could be carried by existing roads if prices obtainable for it there would justify its shipment. Whether the price of these products can be reduced is mainly a question whether the cost of transportation can be lessened. As I have stated, in one case during the last year, this cost to the consumer, and not the railroad company, was from 7 to 8 mills per ton per mile, which I believe can be considerably reduced.

Take, for instance, the item of dead weight: A common well-built country wagon, weighing about 800 pounds, will carry 3,000 on any fair country road, and without injury pass over obstructions which cause it to fall one, two or more inches, the paying weight being about 79 per cent. of the whole. The ordinary box-car in use upon our railways at the present time weighs about 10 tons; its maximum load is generally about 11 tons, while its average load is about 8 tons; the paying weight being from 44 to 52 per cent. of the whole. It does not seem reasonable that the weight of a car constructed to run upon a smooth even track, without a fall, should be so disproportioned to the load carried. The proper relation and proportion to each other of the different parts of railway machinery is a subject worthy of consideration by the best engineers.

What amount of tonnage may be carried over a railroad is, to a great extent, a matter of speculation; but if, as has been already projected, a double-track railroad were exclusively used for a freight traffic, with its trains always running at a uniform speed, without turning out or laying over, it is manifest that many trains could be moved on the two tracks. The ordinary rule is for freight trains to follow each other 5 min. apart, but by the English block system, or a similar one, this may be reduced to 2 min. If 10 min. are allowed between trains, and the cars are of construction and engines of power so that each train will carry 200 tons (more than which is done on many railroads now), 1,200 tons would pass in one direction every hour. 1,000 tons per hour would be 24,000 tons a day, and 7,200,000 tons in a year of 300 working days, which is much more than was carried last year by the four trunk lines between the East and the West, as stated in this discussion. In an engineering point of view, there is nothing improbable in that. I will not attempt to compare the cost of carrying 7,000,000 tons on one railway with that of carrying 2,000,000 tons on four; evidently it would be much below the least sum already stated as the cost on one, if not all, of these four first-class railroads, namely, 7 mills per ton per mile.

A short time ago the "Pittsburgh Commercial," a paper that generally presents

enlightened views, "in an article on this subject of transportation," suggested that if a railroad were devoted exclusively to freight traffic, and operated by parties who owned and run the cars they used (and by inference the locomotives also, although it was not so stated), the same as boats are now owned and run on the canals, the present cost to the consumer would be reduced three-fourths. Cereals grown in Iowa, Kentucky, Missouri, and other Western States, are transported to the seaboard, at an average cost for the whole year less than 1 cent per ton per mile, therefore this article assumed that it could be done for 2½ or 3 mills. Statements so far from fact fail to engage the attention of transporters, and lead to no good result.

A complete and authoritative investigation into the cost of transportation, made by intelligent parties, capable of deducing principles from established data, would not only be very instructive to engineers and railway managers, but of vast importance to the country at large. There is nothing of the kind now, nor can I suggest the source from whence any authoritative statement may be expected, unless it is this Society.

Mr. Rothwell—In regard to the utilization of waste coal, alluded to in the paper read, it may be said that engineers and railroad men are more interested in the consumption of coal than in the details of mining. What the quantity of that consumption shall be, depends much upon the cost of coal where it is used, which, of course, varies with the charges for freight, the amount of waste, and the expense of mining.

The waste of coal occurs either in mining, preparation for market, or transportation and storage. My estimates of the quantity lost in mining mostly refer to anthracite coal, though they would apply to the bituminous coal of this country; the two being generally mined on the same system—that of chambers and pillars, whereby a portion of the coal is taken out in rooms, and the remainder left to sustain the roof. In mines worked at moderate depths, up to 300 or 400 ft., and where consequently the pressure of the overlying strata is small, not less than 25 per cent. of the coal is left in pillars; probably 33 per cent. will nearly represent the average in mines of various depths.

A great portion of the 67 per cent. taken out is broken into sizes to suit the market. This has been done so long that consumers expect it, although usually the coal could be burned in lumps or broken where used, and the resulting waste avoided; for which, as well as the cost of breaking at the mines, the consumer, of course, has to pay. In preparing coal for market—that is, breaking, screening, and washing it—the waste varies from 15 to 45 per cent.; where crushers with sharp steel teeth, and other suitable machinery are used, this is much reduced, and perhaps 25 per cent. may be taken as an average loss from this cause. The fine coal in the anthracite region is thrown aside as useless. Attempts have been made to manufacture it into a compressed fuel, which was found to cost more than the coal in lumps.

Then there is the waste in transportation. Most of the coal cars used for transporting anthracite coal have high bodies, whence the shutes from which they are loaded are about 8½ ft. above the track; the coal falls from them to the bottom of the car, and consequently a portion of it is broken. It is then carried at considerable speed, especially where there is a down grade, over the roads, some of which are pretty rough. Experience shows that the breakage varies very much with the speed of the trains; in bituminous coal it is more apparent than in anthracite; and in either case there is a larger percentage broken in transportation than most engineers suppose. When there are different sizes of coal in the same car the smaller fills up between the larger, and a less quantity is crushed. This fine coal, if bituminous, can be readily used at the end of the route; a large part of the anthracite dust is sold, but at a reduced price, and the difference added to that of good marketable coal. Probably the form of cars could be changed so as to lessen this item of waste.

The loss in volatile matter—and even in fixed carbon—which coal, and particularly bituminous coal, undergoes, when allowed to heat in heaps exposed to the weather, amounts sometimes to 10, and possibly even 20 or more per cent. Coal should be kept dry, cool, and under cover—an important matter well worth the consideration of railroad managers.

These are the principal items of loss. This Society of Civil Engineers, perhaps, is not so much interested in the mining of coal as its transportation; still, whatever affects the cost in the market of this prime commodity should receive attention from

railroad, scarcely less than from mining, engineers. The question of the waste of coal is being examined by a committee of our sister society—the American Institute of Mining Engineers, of which I have the honor to be a member; the committee has been more than a year engaged in collecting information, and, without doubt, the result of the investigation will have an important bearing upon the subject of mining and preparing coal.

Mr. McAlpine—I stated that ⅔ of all the freight from the West to the tide water went by two canals—chiefly by the Erie; that left but 2,000,000 tons to be carried by the four trunk railroads altogether. Reports referred to in my address before the Chamber of Commerce, show how much was actually transported both ways; although the quantity of freight is large, during the year these roads together moved eastward only 2,000,000 tons of through freight, which is the class I alluded to.

I would mention that thirty years ago I ascertained the tonnage from the West to tide water by all the railways and water lines, to be nearly four times as much as that from tide water to the West, while the values of the two were nearly equal.

Mr. Shinn—The statements I made of the cost of transportation were not of that upon a model railroad, but based on the work actually done by existing railways during the past year; they were made after full deliberation, and result from due investigation. I am prepared to prove them, and when I can possibly find the time, I will do so in detail.

ON FUEL.*

By C. WILLIAM SIEMENS, D. C. L., F. R. S.

In accepting the invitation of the Council of the British Association to deliver an address to the operative classes of this great industrial district, I felt that I was undertaking no easy task. Having to speak on behalf of the Association, and in the presence of many of its most distinguished members, I am bound to treat my subject scientifically; but I have to bear in mind at the same time that I am addressing myself to men unquestionably of good intelligence, but without that scientific training which has almost created a language of its own.

It is no consolation for me to think that those who have taken a similar task upon themselves in former years, have admirably succeeded in divesting highly scientific subjects of the formalism in which they are habitually clothed. The very names of these men—Tyndall, Huxley, Miller, Lubbock, and Spottiswoode—are such as to preclude in me all idea of rivalry, but I hope to profit by their example, and to remember that truth must always be simple, and that it is only where knowledge is imperfect that scientific formulæ must take the place of plain statements.

The subject matter of my discourse is "Fuel;" a matter with which every one of us has become familiarized from his infancy, but which nevertheless is but little understood even by those who are most largely interested in its applications; it involves considerations of the highest *à priori* interest, both from a scientific and a practical point of view.

I purpose to arrange my subject under five pricipal heads:—

1. What is fuel?
2. Whence is fuel derived?
3. How should fuel be used?
4. The coal question of the day?
5. Wherein consists the fuel of the sun?

WHAT IS FUEL?

Some of you may have already said within yourselves that it is but wasted time to enlarge upon such a theme, since all know that fuel is coal drawn from the earth, from deposits, with which this country especially has been bountifully supplied; why disturb our plain understanding by scientific definitions which will neither reduce the cost of coal, nor make it last longer on our domestic hearth?

Yet I must claim your patience for a little, lest, if we do not first agree upon the essential nature of fuel, we may afterwards be at variance in discussing its origin and its uses, the latter at any rate being of practical interest, and a subject worthy of your most attentive consideration.

Fuel, then, in the ordinary acceptation

* A Lecture delivered to the Operative Classes at Bradford on behalf of the British Association.

of the term, is carbonaceous matter, which may be in the solid, the liquid, or in the gaseous condition, and which, in combining with oxygen, gives rise to the phenomenon of heat. Commonly speaking, this development of heat is accompanied by flame, because the substance produced in combustion is gaseous. In burning coal, for instance, on a fire-grate, the oxygen of the atmosphere enters into combination with the solid carbon of the coal and produces carbonic acid, a gas which enters the atmosphere, of which it forms a necessary constituent, since without it, the growth of trees and other plants would be impossible. But combustion is not necessarily accompanied by flame, or even by a display of intense heat. The metal magnesium burns with a great display of light and heat, but without flame, because the product of combustion is not a gas but a solid, viz., oxide of magnesium. Again, metallic iron, if in a finely divided state, ignites when exposed to the atmosphere, giving rise to the phenomena of heat and light without flame, because the result of combustion is iron oxide or rust; but the same iron, if presented to the atmosphere—more especially to a damp atmosphere—in a solid condition, does not ignite, but is nevertheless gradually converted into metallic oxide or rust as before.

Here, then, we have combination without the phenomena either of flame or light; but by careful experiment we should find that heat is nevertheless produced, and that the amount of heat so produced precisely equals that obtained more rapidly in exposing pulverulent iron to the action of oxygen. Only, in the latter case the heat is developed by slow degrees, and is dispersed as soon as produced, whereas in the former the rate of production exceeds the rate of dispersion, and heat, therefore, accumulates to the extent of raising the mass to redness. It is evident from these experiments that we have to widen our conception, and call fuel "any substance which is capable of entering into combination with another substance, and in so doing gives rise to the phenomenon of heat."

In thus defining fuel, it might appear at first sight that we should find upon our earth a great variety, and an inexhaustible supply of substances that might be ranged under this head; but a closer investigation will soon reveal the fact, that its supply is, comparatively speaking, extremely limited.

In looking at the solid crust of the earth, we find it to be composed for the most part of siliceous, calcareous, and magneceous rock; the former, silica, consisting of the metal silicon combined with oxygen, is not fuel, but rather a burnt substance which has parted with its heat of combustion ages ago; the second, limestone, being carbonate of lime, or the combination of two substances, viz., calcic oxide and carbonic acid, both of which are essentially products of combustion, the one of the metal calcium, and the other of carbon; and the third, magnesia, a combination of oxygen with the metal magnesium (which I have just burnt before you), and which, further combined with lime, constitutes dolomite rock, of which the Alps are mainly composed. All the commoner metals, such as iron, zinc, tin, aluminium, sodium, etc., we find in nature in an oxidized or burnt condition; and the only metallic substances that have resisted the intense oxidizing action that must have prevailed at one period of the earth's creation are the so-called precious metals, gold, platinum, iridium, and to some extent also silver and copper. Excepting these, coal alone presents itself as carbon and hydrogen in an unoxidzed condition. But what about the oceans of water, which have occasionally been cited as representing a vast store of heat-producing power ready for our use when coal shall be exhausted. Not many months ago, indeed, on the occasion of a water gas company being formed, statements to this effect could be seen in some of our leading papers. Nothing, however, could be more fallacious. When hydrogen burns, doubtless a great development of heat ensues, but water is already the result of this combustion (which took place upon our globe before the ocean was formed), and the separation of these two substances would take precisely the same amount of heat as was originally produced in their combustion. It will thus be seen that both the solid and fluid constituents of our earth, with the exception of coal, of naphtha (which is a mere modification of coal), and the precious metals, are products of combustion, and therefore the very reverse of fuel. Our earth may indeed be looked upon as "a ball of cinder, rolling unceasingly through space," but happily in company with another celestial body—the sun,—whose glorious beams are the physical cause of everything that moves and lives, or that has the power within itself of

imparting life, or motion on our earth. This invigorating influence is made perceptible to our senses in the form of heat, but it is fair to ask, what is heat, that it should be capable of coming to us from the sun, and of being treasured up in our fuel deposits both below and on the surface of the earth?

If this inquiry had been put to me 30 years ago, I should have been much perplexed. By reference to books on Physical Science, I should have learnt that heat was a subtle fluid which, somehow or other, had taken up its residence in the fuel, and which, upon ignition of the latter, was sallying forth either to vanish or to abide elsewhere; but I should not have been able to associate the two ideas of combustion and development of heat by any intelligible principle in nature, or to suggest any process by which it could have been derived from the sun and petrified, or, as the empty phrase ran, rendered latent in the fuel.

It is by the labors of Mayer, Joule, and other modern physicists, that we are enabled to give to heat its true significance.

Heat, according to the "dynamical theory," is neither more nor less than motion amongst the particles of the substance heated, which motion, when once produced, may be changed in its direction and its nature, and thus be converted into mechanical effect, expressible in foot pounds, or horse power. By intensifying this motion among the particles, it is made evident to our visual organ by the emanation of light, which again is neither more nor less than vibratory motion imparted by the ignited substance to the medium separating us from the same. According to this theory, which constitutes one of the most important advances in science of the present century, heat, light, electricity, and chemical action are only different manifestations of "energy of matter," mutually convertible, but as indestructible as matter itself.

Energy exists in two forms, "dynamic" or "kinatic energy," or force manifesting itself to our senses as weight in motion, as sensible heat, or as an active electrical current; and "potential energy," or force in a dormant condition. In illustration of these two forms of energy, I will take the case of lifting a weight, say one pound one foot high. In lifting this weight kinatic, muscular energy has to be exercised in overcoming the force of gravitation of the earth. The pound weight when supported at the higher level to which it has been raised, represents "potential energy" to the amount of one unit or "foot pound." This potential energy may be utilized, in imparting motion to mechanism, during its descent, whereby a unit amount of "Work" is accomplished. A pound of carbon then, when raised through the space of one foot from the earth, represents, mechanically speaking, a unit quantity of energy, but the same pound of carbon when separated or, so to speak, lifted away from oxygen, to which it has a very powerful attraction, is capable of developing no less than 11,000,000 foot pounds or unit quantities of energy whenever the bar to their combination, namely, excessive depression of temperature, is removed; in other words, the mechanical energy set free in the combustion of 1 lb. of pure carbon is the same as would be required to raise 11,000,000 * lbs. weight 1 ft. high, or as would sustain the work which we call a horse power during 5 hours 33 min. We thus arrive at once at the utmost limit of work which we can ever hope to accomplish by the combustion of 1 lb. of carbonaceous matter, and we shall presently see how far we are still removed in our practice from this limit of perfection.

The following illustrations will show the convertibility of the different forms of energy. If I let the weight of a hammer descend in rapid succession upon a piece of iron it becomes hot, and on beating a nail thus vigorously and skilfully for a minute it will be red-hot. In this case the mechanical force developed in the arm (by the expenditure of muscular fibre) is converted into heat. Again, in rapidly compressing the air in a fire syringe, ignition of a piece of tinder is obtained. Again, in passing an electrical current through the platinum wire it is directly converted into heat, which is manifested by ignition of the wire, whereas the thermopile gives an illustration of the conversion of heat into electricity; to which illustrations many others might be added. The heat of combustion being the result of the chemical combination of two substances, does it not follow that oxygen is a combustible as well

* In burning 1 lb. of carbon in the presence of free oxygen, carbonic acid is produced and 14,500 units of heat (a unit of heat is 1 lb. of water raised through 1 deg. Fah.) are liberated. Each unit of heat is convertible (as proved by the deductions of Mayer and the actual measurements of Joule) into 774 units of force or mechanical energy; hence 1 lb. of carbon represents really $14,500 \times 774 = 11,223,000$ units of potential energy.

as the carbonaceous substance which goes by the name of fuel? This is, unquestionably, the case, and if our atmosphere was composed of a carbonaceous gas, we should have to conduct our oxygen through tubes and send it out through burners to supply us with light and heat, as will be seen by the experiment in which I burn a jet of atmospheric air in a transparent globe filled with common lighting gas; but we could not exist under such inverted conditions, and may safely strike out oxygen and analogous substances, such as chlorine, from the list of fuels.

We now approach the second part of our inquiry—

WHENCE IS FUEL DERIVED?

The rays of the sun represent energy in the form of heat and light, which is communicated to our earth through the transparent medium which must necessarily fill the space between us and our great luminary. If these rays fall upon the growing plant, their effect disappears from direct recognition by our senses, inasmuch as the leaf does not become heated as it would if it were made of iron or dead wood, but we find a chemical result accomplished, viz., carbonic acid gas, which has been absorbed by the leaf of the tree from the atmosphere, is there "dissociated," or separated into its elements, carbon and oxygen, the oxygen being returned to the atmosphere, and the carbon retained to form the solid substance of the tree.

The sun thus imparts 11,000,000 units of energy to the tree for the formation of 1 lb. of carbon in the shape of woody fibre, and these 11,000,000 units of energy will be simply resuscitated when the wood is burnt, or again combined with oxygen to form carbonic acid.

Fuel, then, is derived through solar energy acting on the surface of our earth.

But what about the stores of mineral fuel, of coal, which we find within its folds? How did they escape the general combustion which, as we have seen, has consumed all other elementary substances? The answer is a simple one. These deposits of mineral fuel are the results of primeval forests, formed in the manner of to-day, through the agency of solar rays, and covered over with earthy matter in the many inundations and convulsions of the globe's surface, which must have followed the early solidification of its surface. Thus our deposits of coal may be looked upon as the accumulation of potential energy derived directly from the sun in former ages, or as George Stephenson, with a sagacity of mind in advance of the science of his day, answered, when asked what was the ultimate cause of motion of his locomotive engine, "that it went by the bottled-up rays of the sun."

It follows from these considerations that the amount of potential energy available for our use is confined to our deposits of coal, which, as appears from the exhaustive inquiries lately made by the Royal Coal Commission, are still large indeed, but by no means inexhaustible, if we bear in mind that our requirements will be ever on the increase, and that the getting of coal will become from year to year more difficult as we descend to greater depth. To these stores must be reckoned lignite and peat, which, although not coal, are nevertheless the result of solar energy, attributable to a period of the earth's creation subsequent to the formation of the coal beds, but anterior to our own days. These fuels may be made as efficient as coal if properly treated.

In discussing the necessity of using our stores of fuel more economically, I have been met by the observation that we need not be anxious about leaving fuel for our descendants—that the human mind would surely invent some other source of power when coal should be exhausted, and that such a source would probably be discovered in electricity. I heard such a suggestion publicly made only a few weeks back at a meeting of the International Jury at Vienna, and could not refrain from calling attention to the fact that electricity is only another form of energy, that could no more be created by man than heat could, and involved the same recourse to our accumulated stores.

If our stores of coal were to ebb, we should have recourse, no doubt, to the force radiating from the sun from year to year, and from day to day; and it may be as well for us to consider what is the extent of that force, and what are our means of gathering and applying it. We have, then, in the first place the accumulation of solar energy upon our earth's surface by the decomposition of carbonic acid in plants, a source which we know by experience suffices for the human requirements in thinly populated countries, where industry has taken only a slight development. Wherever population accumulates, however, the wood of the

forest no longer suffices even for domestic requirements, and mineral fuel has to be transported from great distances.

The sun's rays produce, however, other effects besides vegetation, and amongst these, that of evaporation is the most important as a source of available power. By the solar rays, an amount of heat is imparted to our earth that would evaporate yearly a layer of water 14 ft. deep. A considerable proportion of this heat is actually expended in evaporating sea water, producing steam or vapor, which falls back upon the entire surface of both land and sea in the form of rain. The portion which falls upon the elevated land flows back towards the sea in the form of rivers, and in its descent its weight may be utilized to give motion to machinery. Water power, therefore, is also the result of solar energy, and an elevated lake may indeed be looked upon as fuel, in the sense of its being a weight lifted above the sea level through its prior expansion into steam.

This source of power has also been largely resorted to, and might be utilized to a still greater extent in mountainous countries; but it naturally so happens that the great centres of industry are in the plains, where the means of transport are easy, and the total amount of available water-power in such districts is extremely limited.

Another result of solar energy are the winds, which have been utilized for the production of power. This source of power is, indeed, very great in the aggregate, but its application is attended with very great inconvenience. It is proverbial that there is nothing more uncertain than the wind, and when we were dependent upon windmills for the production of flour, it often happened that whole districts were without that necessary element to our daily existence.

Ships also, relying upon the wind for their propulsion through the sea, are often becalmed for weeks, and so gradually give place to steam-power on account of its greater certainty. It has been suggested of late years to utilize the heat of the sun by the accumulation of its rays into a focus by means of gigantic lenses, and to establish steam-boilers in such foci. This would be a most direct utilization of solar energy, but it is a plan which would hardly recommend itself in this country, where the sun is but rarely seen, and which even in a country like Spain would hardly be productive of useful practical results.

There is one more natural source of energy available for our uses, which is rather cosmical than solar—viz., the tidal wave. This might also be utilized to a very considerable extent in an island country, facing the Atlantic seas, like this, but its utilization on a large scale is connected with great practical difficulty and expenditure, on account of the enormous area of tidal basin that would have to be constructed.

In passing in review these various sources of energy which are still available to us, after we have run through our accumulated capital of potential energy in the shape of coal, it will have struck you that none of them would at all supply the place of our willing and ever-ready slave—the steam-engine; nor would they be applicable to our purposes of locomotion, although means might possibly be invented of storing and carrying potential energy in other forms. But it is not force alone that we require, but heat for smelting our iron and other metals, and the accomplishment of other chemical processes. We also need a large supply for our domestic purposes. It is true that with an abundant supply of mechanical force we could manufacture heat, and thus actually accomplish all our purposes of smelting, cooking, and heating, without the use of any combustible matter; but such conversion would be attended with so much difficulty and expenditure that one cannot conceive human prosperity under such laborious and artificial conditions.

We come now to the question—

HOW SHOULD FUEL BE USED?

I propose to illustrate this by three examples which are typical of the three great branches of consumption:

a. The production of steam power.

b. The domestic hearth.

c. The metallurgical furnace.

Steam Engine Consumption.—I have represented on a diagram two steam cylinders of the same internal dimensions, the one being what is called a high-pressure steam cylinder, provided with the ordinary slide valve for the admission of steam and its subsequent discharge into the atmosphere, and the other so arranged as to use the steam expansively (being provided with the Corliss variable expansion gear) and working in

connection with a condenser. I have also shown two diagrams of the steam pressures at each part of the stroke, assuming in both cases the same initial steam pressure of 60 lbs. per square inch above the atmospheric pressure, and the same load upon the engine. They show that in the latter case the same amount of work is accomplished by filling the cylinder, roughly speaking, up to $\frac{1}{3}$ part of the length as in the other by filling it entirely. Here we have then an easy and feasible plan of saving $\frac{2}{3}$ of the fuel used in working an ordinary high-pressure engine, and yet probably the greater number of the engines now actually at work are of the wasteful type. Nor are the indications of theory in this case (or in any other when properly interpreted) disproved by practice; on the contrary, an ordinary non-expansive non-condensing engine requires commonly a consumption of from 10 to 12 lbs. per horse power per hour, whereas a good expansive and condensing engine accomplishes the same amount of work with 2 lbs. of coal per hour, the reason for the still greater economy being, that the cylinder of the good engine is properly protected by means of a steam jacket and lagging against loss by condensation within the working cylinder, and that more care is generally bestowed upon the boiler and the parts of the engine, to insure their proper working condition.

A striking illustration of what can be accomplished in a short space of time was brought to light by the Institute of Mechanical Engineers, over which I have at present the honor to preside. In holding their annual general meeting in Liverpool in 1863, they instituted a careful inquiry into the consumption of coal by the best engines in the Atlantic Steam Service, and the result showed that it fell in no case below $4\frac{1}{2}$ lbs. per indicated horse power per hour. Last year they again assembled with the same object in view, in Liverpool, and Mr. Bramwell produced a table showing that the average consumption by 17 good examples of compound expansive engines did not exceed $2\frac{1}{4}$ lbs. per indicated horse power per hour. Mr. E. A. Cowper has proved a consumption as low as $1\frac{1}{2}$ lbs. per indicated horse power per hour in a compound marine engine, constructed by him with an intermediate superheating vessel. Nor are we likely to stop long at this point of comparative perfection, for in the early portion of my address I have endeavored to prove that theoretical perfection would only be attained if an indicated horse power were produced with $\frac{1}{3.3}$ lb. pure carbon, or say $\frac{1}{4}$ lb. of ordinary steam coal per hour.

Here then we have two distinct margins to work upon, the one up to the limit of say 2 lbs. of coal per horse power per hour, which has been practically reached in some and may be reached in most cases, and the other up to the theoretical limit of $\frac{1}{4}$ lb. per horse power per hour; which can never be absolutely reached, but which inventive power may and will enable us to approach!

Domestic Consumption.—The wastefulness of the domestic hearth and kitchen fire is self-evident. Here only the heat radiated from the fire itself is utilized, and the combustion is generally extremely imperfect, because the iron back, and excessive supply of cold air, check combustion before it is half completed. We know that we can heat a room much more economically by means of a German stove, but to this it may be very properly objected that it is cheerless because we do not see the fire or feel its drying effect upon our damp clothing; moreover, it does not provide in a sufficient degree for ventilation, and makes the room feel stuffy. These are, in my opinion, very weighty objections, and economy would not be worth having if it could only be obtained at the expense of health and comfort. But there is at least one grate that combines an increased amount of comfort with reasonable economy, and which, although accessible to all, is as yet very little used. I refer to Captain Galton's "Ventilating Fireplace," of which you observe a diagram upon the wall. This fireplace does not differ in external appearance from an ordinary grate, except that it has a higher brick back, which is perforated at about midheight to admit warmed air into the fire so as to burn a large proportion of the smoke which is usually sent up the chimney unburnt, for no better purpose than to poison the atmosphere which we have to breathe.

The chief novelty and merit of Captain Galton's fireplace consists, however, in providing a chamber at the back of the grate, into which air passes directly from without, becomes moderately heated (to 84 deg. Fah.), and, rising in a separate flue, is injected into the room under the ceiling with a force due to the heated ascending flue. A plenum of pressure is thus established within the room whereby indraughts through doors and windows are avoided, and the air is

continually renewed by passing away through the fireplace chimney as usual. Thus the cheerfulness of an open fire, the comfort of a room filled with fresh but moderately warmed air, and great economy of fuel, are happily combined with unquestionable efficiency and simplicity; and yet this grate is little used, although it has been fully described in papers communicated by Captain Galton, and in an elaborate report made by General Morin, le Directeur du Conservatoire des Arts et Metiers of Paris, which has also appeared in the English language.

The slowness with which this unquestionable improvement finds practical application is due, in my opinion, to two circumstances,—the one is, that Captain Galton did not patent his improvement, which makes it nobody's business to force it into use, and the other may be found in the circumstance that houses are, to a great extent, built only to be sold and not to be lived in. A builder thinks it a good speculation to construct a score of houses after a cheap design, in order to sell them, if possible, before completion, and the purchaser immediately puts up the standard bill of "Desirable Residences to Let." You naturally would think that in taking such a house you had only to furnish it to your own mind, and be in the enjoyment of all reasonable creature comfort from the moment you enter the same. This fond hope is destined, however, to cruel disappointment; the first evening you turn on the gas, you find that although the pipes are there, the gas prefers to pass out by the joints into the room instead of by the burners; the water in like manner takes its road through the ceiling, bringing down with it a patch of plaster on to your carpet. But, worst of all, the products of combustion from the firegrates (made probably to dimensions irrespective of the size of the room), stoutly refuse to avail themselves of the chimney flues, preferring to disperse themselves in volumes of smoke into the room. Plumbers and chimney doctors are now put into requisition, pulling up floors, dirtying carpets, and putting up gauntlooking chimney-pots; the grates themselves have to be altered again and again, until by slow degrees the house becomes habitable in a degree, although you now only become fully aware of the innumerable drawbacks of the arrangements adopted. Nevertheless, the house has been an excellent one "to sell," and the builder adopts the same pattern for another block or two in an increasing neighborhood. Why should this builder adopt Captain Galton's fireplace? It will not cost him much, it is true, and it will save the tenant a great deal in his annual coal bill, not to speak of the comfort it would give him and his family; but nobody demands it of him, it would give him some trouble to arrange his details and subcontracts, which are all settled beforehand, and so he goes on building and selling houses in the usual routine way. Nor will this state of things be altered until the dwellers in houses will take the matter in hand, and absolutely refuse to put up with builders' ways, or, what is still better, get builders who will put up houses in their way. This is done to some extent by building societies, but there is as yet too much of the old leaven left in the trade, and the question itself is too little understood.

Consumption in Smelting Operations.—We now come to the third branch of consumption, the smelting or metallurgical furnace, which consumes about 40,000,000 of the 120,000,000 tons of the coal produced. Here also is great room for improvement; the actual quantity of fuel consumed in heating a ton of iron up to the welding point, or in melting a ton of steel, is more in excess of the theoretical quantity required for these purposes than is the case with regard to the production of steam power and to domestic consumption. Taking the specific heat of iron at .114 and the welding heat at 2,900 deg. Fahrenheit, it would require $.114 \times 2{,}900 = 331$ heat units to heat 1 lb. of iron. A pound of pure carbon develops 14,500 heat units, a pound of common coal say 12,000, and therefore one ton of coal should bring 36 tons of iron up to the welding point. In an ordinary reheating furnace a ton of coal heats only $1\frac{3}{4}$ ton of iron, and therefore produces only $\frac{1}{20}$ part of the maximum theoretical effect. In melting one ton of steel in pots $2\frac{1}{2}$ tons of coke are consumed, and taking the melting point of steel at 3,600 deg. Fahrenheit, the specific heat at .119, it takes $.119 \times 3{,}600 = 428$ heat units to melt a pound of steel, and taking the heat-producing power of common coke also at 12,000 units, one ton of coke ought to be able to melt 28 tons of steel. The Sheffield pot steel melting furnace therefore only utilizes $\frac{1}{70}$th part of the theoretical heat developed in the combus-

tion. Here therefore is a very wide margin for improvement, to which I have specially devoted my attention for many years, and not without the attainment of useful results. Since the year 1846, or very shortly after the first announcement of the dynamical theory, I have devoted my attention to a realization of some of the economic results which that theory rendered feasible, fixing upon the regenerator as the appliance which, without being capable of reproducing heat when once really consumed, is extremely useful for temporarily storing such heat as cannot be immediately utilized, in order to impart it to the fluid or other substance which is employed in continuation of the operation of heating, or of generating force.

Without troubling you with an account of the gradual progress of these improvements, in which my brother Frederick has taken an important part, I will describe to you shortly the furnace which I now employ for melting steel. It consists of a bed made of very refractory material, such as pure silica, sand and silica or Dinas brick under which 4 regenerators (or chambers filled with checkerwork of brick) are arranged in such a manner, that a current of combustible gas passes upward through one of these regenerators, while a current of air passes upwards through the adjoing regenerator, in order to meet in combustion at the entrance into the furnace chamber. The products of combustion, instead of passing directly to the chimney as in an ordinary furnace, are directed downwards through the two other regenerators on their way towards the chimney, where they part with their heat to the checkerwork in such manner that the highest degree of heat is imparted to the upper layers, and that the gaseous products reach the chimney comparatively cool (about 300 deg. Fah.). After going on in this way for half an hour, the currents are reversed by means of suitable reversing valves, and the cold air and combustible gas now enter the furnace chamber, after having taken up heat from the regenerators in the reverse order in which it was deposited, reaching the furnace therefore nearly at the temperature at which the gases of combustion left the same. A great accumulation of temperature within the regenerators is the result, one pair being heated while the other pair is being cooled; it is easy to conceive that, in this way, heat may be produced within the furnace chamber up to an apparently unlimited degree, and with a minimum amount of chimney draught.

Practically the limit is reached at the point where the materials composing the furnace chamber begin to melt. Whereas a theoretical limit also exists in the fact that combustion ceases at a point which has been laid down by St. Clair Deville at 4,500 deg. Fah., and which has been called by him the point of "dissociation." At this point hydrogen might be mixed with oxygen and yet the two would not combine, showing that combustion really only takes place btween the limits of temperature of about 600 and 4,500 deg. Fah.

To return to the regenerative gas furnace. It is evident that there must be economy where, within ordinary limits, any degree of heat can be obtained, while the products of combustion pass in the chimney only 300 deg. hot. Practically a ton of steel is melted in this furnace with 12 cwt. of small coal consumed in the gas producer, which latter may be placed at any reasonable distance from the furnace, and consists of a brick chamber containing several tons of fuel in a state of slow disintegration. In large works, a considerable number of these gas-producers are connected by tubes or flues with a number of furnaces. Collateral advantages in this system of heating are, that no smoke is produced, and that the works are not encumbered with solid fuel and ashes.

It is a favorite project of mine, which I have not had an opportunity yet of carrying practically into effect, to place these gas producers at the bottom of coal-pits. A gas shaft would have to be provided to conduct the gas to the surface, the lifting of coal would be saved, and the gas in its ascent would accumulate such an amount of forward pressure that it might be conducted for a distance of several miles to the works or places of consumption. This plan, so far from being dangerous, would insure a very perfect ventilation of the mine, and would enable us to utilize those waste deposits of small coal (amounting on the average to 20 per cent.) which are now left unutilized within the pit.

Another plan of the future which has occupied my attention is the supply of towns with heating gas for domestic and manufacturing purposes. In the year 1863 a company was formed, with the concurrence of the Corporation of Birmingham, to

provide such a supply in that town at the rate of 6d. per 1,000 cubic ft.; but the Bill necessary for that purpose was thrown out in Committee of the House of Lords because their Lordships thought that if this was as good a plan as it was represented to be, the existing gas companies would be sure to carry it into effect. I need hardly say that the existing companies have not carried it into effect, having been constituted for another object, and that the realization of the plan itself has been indefinitely postponed. It has, however, lately been taken up and partly carried into effect at Berlin.

COAL QUESTION.

Having now passed in review the principal applications of fuel, with a view chiefly to draw the distinction between our actual consumption and the consumption that would result if our most improved practice were made general; and having, moreover, endeavored to prove to you what are the ultimate limits of consumption which are absolutely fixed by theory, but which we shall never be able to realize completely, I will now apply my reasoning to the coal question of the day.

In looking into the "Report of the Select Committee appointed to Inquire into the Causes of the Present Dearness of Coal," we find that in 1872 no less than 123,000,000 tons of coal was got up from the mines of England and Wales, notwithstanding famine prices and the colliers' strikes. In 1862 the total getting of coal amounted to only 83,500,000, showing a yearly average increase of production of 4,000,000 tons. If this progressive increase continues, our production will have reached, 30 years hence, the startling figure of 250,000,000 tons per annum; which would probably result in an increase of price very much in excess of the limits yet reached. In estimating last year's increase of price, which has every appearance of being permanent, at 8s. per ton all round, and after deducting the 13,000,000 tons which were exported abroad, we find that the British consumer had to pay £44,000,000 more than the market value of former years for his supply of coal—a sufficient sum, one would think, to make him look earnestly into the question of "waste of fuel," which, as I have been endeavoring to show, is very great indeed. The Select Committee just quoted sums up its report by the following expression:—"The general conclusion to be drawn from the whole evidence is, that though the production of coal increased in 1872 in a smaller ratio than it had increased in the years immediately preceding, yet if an adequate supply of labor can be obtained, the increase of production will shortly keep pace with that of the last few years."

This is surely a very insufficient conclusion to be arrived at by a Select Parliamentary Committee after a long and expensive inquiry, and the worst of it is, that it stands in direct contradiction with the corrected table given in the same report, which shows that the progressive increase of production has been fully maintained during the last two years, having amounted to 5,826,000 for 1871, and 5,717,000 for 1872; whereas the average increase during the last ten years has only been 4,000,000 tons! It is to be hoped that Parliament will not rest satisfied with such a negative result, but will insist upon knowing whether a proper balance between the demand and supply of coal cannot be re-established, also what can be done to prevent the wholesale conversion of fuel into useless or positively hurtful results.

In taking the 105,000,000 tons of coal consumed in this country last year for our basis, I estimate that, if we could make up our minds to consume our coal in a careful and judicious manner, according to our present lights, we should be able to reduce that consumption by 50,000,000 tons. The realization of such an economy would certainly involve a very considerable expenditure of capital and must be a work of time; but what I contend is, that our progress in effecting economy ought to be accelerated, in order to establish a balance between the present production and the ever-increasing demand for the effects of heat.

In looking through the statistical returns of the progressive increase of population, of steam power employed, and of production of iron and steel, etc., I find that our necessities increase at a rate of not less than 8 per cent. per annum, whereas our coal consumption increases only at the rate of 4 per cent., showing that the balance of 4 per cent. is met by what may be called our "intellectual progress." Now, considering the enormous margin for improvement before us, I contend that we should not be satisfied with this rate of intellectual progress, involving, as it does, an annual deficit of 4,000,000 tons to be met by increased coal

production, but that we should bring our intellectual progress up to the rate of our industrial progress, by which means we should make the coal production nearly a constant quantity for several generations to come. By that time our successors may be expected to have effected another great step in advance towards the theoretical limit of effect, which, as we have seen, lays so far above any actual result we have as yet attained, that an annual consumption of 10-000,000 tons would give more than the equivalent of the heat energy which we actually require.

SOLAR HEAT.

I have endeavored to show, in the early part of this lecture, that all available energy upon the earth, excepting the tidal wave, is derived from the sun, and that the amount of heat radiated year by year upon our earth, could be measured by the evaporation of a layer of water 14 ft. deep spread over the entire surface, which again would be represented by the combustion of a layer of coal 8 in. in thickness, covering our entire globe. It must, however, be taken into account that three-fourths of this heat is intercepted by our atmosphere, and only one-fourth reaches the earth itself. The amount of heat radiated away from the sun would be represented by the annual combustion of a thickness of coal 17 miles thick, covering its entire surface, and it has been a source of wonderment with natural philosophers how so prodigious an amount of heat could be given off year after year without any appreciable diminution of the sun's heat having become observable.

Recent researches with the spectroscope, chiefly by Mr. Norman Lockyer, have thrown much light upon this question. It is now clearly made out that the sun consists near the surface, if not throughout its mass, of gaseous elementary bodies, and in a great measure of hydrogen gas, which cannot combine with the oxygen present, owing to an excessive elevation of temperature (due to the original great compression), which has been estimated at from 20,000 deg. to 22,000 deg. Fah. This chemically inert and comparatively dark mass of the sun is surrounded by the photosphere, where its gaseous constituents rush into combustion, owing to reduction of temperature in consequence of their expansion and of radiation of heat into space. This photosphere is surrounded in its turn by the chromosphere, consisting of the products of combustion, which, after being cooled down through loss of heat by radiation, sink back, owing to their acquired density, towards the centre of the sun, where they become again intensely heated through compression, and are "dissociated" or split up again into their elements at the expense of internal solar heat. Great convulsions are thus continually produced upon the solar surface, resulting frequently in explosive actions of extraordinary magnitude, when masses of living fire are projected a thousand miles or more upward, giving rise to the phenomena of sun spots and of the corona which is visible during the total eclipses of the sun. The sun may therefore be looked upon in the light of a gigantic gas-furnace, in which the same materials of combustion are used over and over again.

It would be impossible for me at this late hour to enter further upon speculations regarding the "regeneration of the sun's heat upon its surface," which is a question replete with scientific and also practical interest. We should always remember that nature is our safest teacher, and that in trying to comprehend the great works of our Creator we shall learn how to utilize to the best advantage those stores of potential energy in the shape of fuel which have providentially been placed at our disposal.

A NOTE ON THE RESISTANCE OF MATERIALS.*

By Prof. ROBERT H. THURSTON.

On the 13th ultimo, an apparatus for determining the torsional resistance of materials, which I had designed for use, in illustration of my course of instruction, and to which I had fitted an automatic recording attachment, was exhibited to the National Academy of Science, at the late session held at this place, for the purpose of showing the peculiar adaptability of

* A paper read before the American Society of Civil Engineers.

the machine for the determination and analysis of the action of physical and molecular forces in resisting stress, and to illustrate the bearing of experiments already made upon scientific investigations of molecular relations.

At the close of the meeting, a test piece of wrought iron was left in the machine, exposed to a strain which had passed the limit of elasticity, and with a distortion of 45 deg., the intention being to determine whether, as has been suspected by some writers and by many engineers, "viscosity" is a property of solids, whether a "flow of solids"* could occur under long continued strain just equilibrating, when first applied, the resisting power of the material, or whether the "polarity" of Professor Henry is an absolutely unrelaxing force.

The metal was left under strain 24 hours, and had not then yielded in the slightest degree. This result, and the results of other similar experiments since made confirming it, indicates, that metal strained far beyond the limit of elasticity, as above described, does not lose its power of resisting unintermitted static stress.

The important bearing of this fact upon the availability of iron, and of steel, which also behaves similarly, for use in constructions exposed to severe strains, is readily seen.

After noting the result obtained as stated, it was attempted to still further distort the test piece, when the unexpected discovery was made that its resisting power was greater than when left the previous day, an increase of resistance being recorded amounting to about 25 per cent. of the maximum registered the preceding day, and approximating closely to the ultimate resistance of the material. Repeated experiments, continued up to the date of writing, confirm the following previously undemonstrated principle: that iron and steel if strained beyond the limit of elasticity, and left under the action of the distorting force which has been found just capable of equilibrating their power of resistance, gain resisting power to a degree which has a limit in amount, approximating closely, if not coinciding with the ultimate resistance of the material, and which had a limit, as to time, in experiments hitherto made, of 3 or 4 days.

Releasing the piece entirely and again submitting it to the same force immediately, does not produce this strengthening action.

There is some evidence, that is confirmed by theoretical dynamic principles, that the increase of strength noted is not accompanied by a change of resilience, but that the gain of resisting power is at the expense of a proportional amount of ductility.

The diagrams obtained during this research will be presented at a future time, when the investigation shall have been completed.

The interest and importance attaching to the discovery of the principles above enunciated, to our profession as well as to science, will, I hope, justify the presentation of this note.

* Von. H. Tresca; Sur l'Ecoulement des Corps Solides. Paris, 1869-72.

THE MANUFACTURE OF COMPRESSED-STONE BRICKS.*

By J. J. BODMER, of London.

From "The Engineering and Mining Journal."

The substances or materials employed in this manufacture, are the same as those used in the preparation of mortar and concrete, viz.: the different kinds of lime and sand. Instead of, or in conjunction with sand there may be used calcined clay, blast-furnace slag, clinkers or ashes from furnaces, natural puzzolana, powdered chippings from stone quarries, etc. Of the different kinds of sand, pit sand—silicious sand, as it commonly occurs mixed with gravel—and the sand found on the seashore, where the salt has been washed out by long exposure, whilst out of reach of the tide, may be used. The purer the above-named materials are from admixtures of clay, earth, or organic substances, the more complete will be their combination with the lime, the quicker will the manufactured brick or block set, and the more satisfactory will be the quality which it ultimately attains. For this reason, subdivided blast-furnace slag is preferable in most

* A paper read before the American Institute of Mining Engineers, at Easton, Pa., Oct. 22, 1873.

cases to sand, and the only sand which in reference to setting capacity is analogous to blast-furnace slag, is the volcanic sand occurring in different localities in North and South Wales as an almost pure calcined silica. The lime used for the manufacture may be either slaked or unslaked. In the first case (slaked), in order to obtain satisfactory results, the lime must be strongly hydraulic. The use of unslaked lime, however, is by far preferable. A process for using fresh or unslaked lime has been patented in England, by Major-General Scott. Lime thus prepared is called "selenitic lime," and consists of a mixture of fresh (unslaked) lime with sulphate of lime, or plaster of Paris. The grey stone lime, for instance, found by the Medway, is mixed with from 5 to 7 per cent. of plaster, which has the effect of keeping the lime from slaking when water is added. This mixture also partakes of the nature of cement, and when used for mortar or concrete, attains in a shorter time a greater degree of hardness than the same lime would ever have obtained after being slaked.

Bodmer's process for the manufacture of artificial stone bricks consists chiefly in the use of automatic measuring, forwarding, and mixing apparatus, by means of which the materials are supplied and unite in a continuous stream, and are accurately measured. They are then mixed and amalgamated automatically in a very perfect manner. Both the lime and the plaster are used in the form of powder. Supposing that two kinds of lime are used, besides plaster, each of these substances is fed into a separate hopper, from which they drop into a measuring apparatus. The outflow and speed of this apparatus is so arranged that, for instance, 80 per cent. of one kind of lime may be fed out during the time in which 20 per cent. of the other kind and 5 per cent. of plaster are delivered.

The stream formed by the three materials then flows into a dry mixing apparatus, in which a most perfect amalgamation of the particles takes place. Issuing from this, it is made to pass through a pair of rolls, going at differential speed, which grind up and rub the particles into each other. The sand, or subdivided slag, is fed into a similar measuring apparatus, from which it issues in a uniform layer on an endless india-rubber belt.

The proportions of sand, or slag, and lime depend chiefly upon the quality of the latter, and may consist of 5 to 8 lbs. or more of sand or slag to 1 lb. of the lime mixture. The lime mixture drops from the rolls upon the travelling layer of sand, or slag (which has been moistened as required, by a watering apparatus), and the several ingredients are made to travel into a mixing drum, and from that to a final amalgamating apparatus. From this last named apparatus the now finished mixture is carried by a belt to the press.

There are three methods of mixture:—

1. *Dry Mixture.*—In this process just as much water is added as is required for complete mixture of the sand and lime, so that on pressure being applied, no moisture is given off. But each grain of sand, or slag, must have its coating or skin of lime.

2. *Half-wet Mixture.*—In this process an excess of water is added; the mass is allowed to lie till this excess is absorbed; and before the mixture begins to set, it is fed into the press. The coating of each particle of sand, or slag, with lime, is in this case more certain and complete, and this process, under certain conditions, possesses many advantages over the foregoing. The dry mixture, however, is more convenient to work, and is giving most satisfactory results.

3. *Wet Mixture.*—In this process still more water is added, and the mixture is simply filled into moulds, or used for mortar and allowed to set without pressure. If instead of, or in conjunction with, lime, cement is used in order to quicken the hardening process, this method (wet mixing) is preferable for forming large blocks, etc.

Pressing.—For the forming or pressing of the bricks a hydraulic press is used, which is supplied by a pump and accumulator. The press has a horizontal turntable, in which there are six pairs of moulds. While two pairs are being filled, by means of a hopper, two others are under pressure; and the last two pairs deliver finished bricks on the surface of the table, from which they are taken off, put on barrows and carried out to the shed, or into the yard, where they are piled up and left until required for use.

From 6 to 8 weeks are required for the hardening of sand and lime bricks. The time depends chiefly on the quality of the sand and lime, and partly on the weather.

The hardening process goes on for years, and the difference in hardness may be observed from month to month.

The before-mentioned press is calculated for seven strokes per minute, that is to say, for a production of 28 bricks per minute. A pressure of 10 cwt. per sq. in., or 20 tons per brick of $9 \times 4\frac{1}{2} \times 2\frac{3}{4}$ in., is found sufficient.

Two men and four boys are required for the whole of the manufacturing process. The number of hands for wheeling and piling the bricks depends upon the distance of the press from the shed or field where the bricks are deposited.

The same principle of press is applicable in the manufacture of bricks from common clay or fire clay; as also for fuel-bricks, asphalt-bricks, and many other descriptions of compressed materials.

Comparative Absorption Tests of Bodmer & Co.'s Patent Stone Bricks and of Clay Bricks.

	Best Gault Clay Bricks.	Best Stock Clay Brick.	Sand and Lime. Brick.	Blast furnace Dry Slag.	Slag and Lime Spongy Slag.
	lb. oz.	lb. oz.	lb. oz.	lb. oz.	lb. oz.
Weighed dry	5 15	4 13	6 9¾	7 7⅛	5 7¾
Weighed wet	7 2¼	5 14⅜	7 1¾	7 12¼	5 14⅜
Water taken up per brick	1 3¼	1 1⅜	0 7⅞	0 4⅞	0 6⅝
Percentage of water taken up	20.26	22.72	7.09	3.97	7.69

The bricks were dried on a heated iron plate and then weighed. They were then immersed for 50 hours in water and again weighed.

Cost of Manufacture of Blast-furnace Slag Bricks in Materials and Wages.

BODMER'S PATENT.

Blast-furnace Slag.		Sifted Lime.		Wages.		Total cost of 1,000 bricks.
Per ton.	Per 1,000 bricks.	Per ton.	Per 1,000 bricks.	Per week.	Per 1,000 bricks.	
s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.
0 6	1 3½	27 0	10 9⅝	169 2	2 1⅝	14 2⅝
0 6	1 3½	25 0	10 0	"	2 1⅝	13 5
0 6	1 3½	22 0	8 9⅛	"	2 1⅝	12 2⅝
0 6	1 3½	20 0	8 0	"	2 1⅝	11 5
0 6	1 3½	18 0	7 2	"	2 1⅝	10 7
0 6	1 3½	16 0	6 4¾	"	2 1⅝	9 9¾
0 6	1 3½	14 0	5 7	"	2 1⅝	9 0

Cost of Sub-dividing Slag.	Per week.
One 4 h. p. engine at 5 lb. per hour per h. p. Coal at 20s. per ton	£1 10 0
Wages: 1 man by day, " 1 " night, at 24 s.	2 8 0
	3 18 0
240 tons of slag at 6d. per ton	6 0 0
Profit per week on slag used	2 2 0
80,000 bricks per week.	per press.

The slag is supposed to be delivered in a sub-divided condition at the brick works.

Weight of bricks about 3 tons per 1,000.

Mixture, 52 cwt. slag with 8 cwt. of lime.

Wages calculated upon 2 men at 5d. per hour, 58 hours per week.

Ten boys at 2½d. per hour, 58 hours per week.

BRICK ARCHITECTURE.

From "The Builder."

The order given by the Egyptian taskmasters to the Israelites, is in substance echoed just now by some active professional practitioners,—"they say unto us, 'make brick'": in other words, there seems to be a decided leaning in certain quarters towards the employment of brick, not as an economical substitute for, but in preference

to, stone. Whether this is the consequence or the cause of some of the studies that have been directed to the architecture of countries where brick is necessarily the staple building material, it is not very easy to say; we should be inclined to think it is rather the former. We have studied and more or less imitated, or adapted, most varieties of European work of the great architectural epoch, so far as style is concerned; and a material hitherto comparatively little used in high class architecture among ourselves, but which in some countries has been so almost exclusively employed as to give its own decided stamp and character to the architecture embodied in it, seems to promise a further change, and suggests new combinations of old things. The discussion which has taken place thereupon is indicative, along with other things, of the wish to find some degree of novelty of architectural expression in the revival or transplantation of some of the feeling of an essentially brick architecture.

From one point of view, certainly, it might be urged that we can have no need to go to other countries to study this class of architecture, when we have a brick architecture, pure and simple, so peculiarly our own, omitting notice of earlier work in this material, filling so many leagues of our streets with its unadorned neatness, and rising to something of monumental grandeur and dignity in the masses of warehouse and factory, to be found in different parts of the kingdom; heaps of bricks, as Fielding somewhere observes, piled up as a kind of token or monument that heaps of money had been piled first. It is all very well to sneer at the "hole-in-the-wall style," but it has at least been a great fact; it is the expression of the sole and comprehensive idea of thousands, we might say millions of people, as to the possibility of architectural expression in the exterior of city, and even of many country, homes; it represents, in one point of view, the readiest, simplest, and most economical way of using a material which can be formed into unlimited numbers of cubes of exactly the same size and proportion; and its merits in its palmy days have attracted the commendation, the sympathetic admiration of a very eminent modern philosopher. It has the quality, specially characteristic of the grandest production of the art, unity and breadth of style; like the Doric temple, it achieves effect by a repetition of similar features; and any section of it, taken separately, is, as a composition, complete in itself. The researches of modern architectural critics, however, are tending to throw contempt on this chaste and severe style of brick architecture, and drawing our attention more and more to the effects produced in other countries by moulded bricks, and tracery, and other *tours de force* of this kind, in burnt clay, from which we may draw wholesome lessons and precedents for transplantation to our own streets and squares.

If we go beyond the pure English style of brick design alluded to, we may distinguish these stages or manners in the employment of the material, two of which have already received considerable illustration in this country. There is the brick and stone style, the colored brick style, and the moulded brick style. The first, vulgarly known as brick with stone dressings, is indigenous, and in many cases is, in fact, merely the substitution of brick for stone in the unornamented parts of the structure, for the sake chiefly of economy; though it may be accompanied by a certain amount of "treatment" of the brick, by the introduction of lines or crosses of darker brick on the orthodox red brick ground. Though this is an imitation in brick and stone of a masonic style, rather than a distinct style, it has, nevertheless, a character of its own, and in old houses especially, where the conflicting brick and stone elements have been toned down by time, it is capable of very pleasing effect. But in more recent times this method of combining the two materials has been the medium for all kinds of architectural commonplaces and vulgarities. It affords a means of getting what is supposed to be an architectural effect at a reduced cost from that of stone, and is eminently useful in the production of the kind of dwellings or shops called "handsome" or "respectable," as the degree of stone embroidery is more or less profuse. It is especially disagreeable when carried out with those staring, cold-looking yellowish bricks, which are the bane of so much modern town architecture; and at the best, the system of combining brick and stone in this way produces patchwork, takes away entirely the homogeneous character of a building, and gives it a kind of put-together cabinet appearance, with what we have heard called the "architectural

features" added and framed into the rest. It would be possible to use brick and stone together in a much more architectural way than this, making a basement of the one and superstructure of the other; for instance, instead of putting the stone in after a carpenter and joiner fashion, to make jambs and architraves to windows and doors. The colored brick architecture is, as far as this country is concerned, of modern origin, or rather importation. As carried out here, it is distinguished by great flatness of treatment, and a frequently violent opposition of strongly-colored patent brick; though lately there have been attempts to realize more delicate harmonies by the combination of stone of suitable tints. The style is, in fact, the importation here of a manner of architectural treatment arising not unnaturally in a southern climate, where there is plenty of light to bring out distinctions of tint, and where material of rich and delicate tints (marble) could be procured, either to be used alone, or to combine with and harmonize the more raw hues of brick and tile work. We have not the same facilities here. We have been smitten with "the brick and marble architecture" of Italy, and have transplanted it, minus the marble, into an atmosphere where we have only two things to choose between in the treatment of external color: either to make it very unpleasantly stray at first, or to see the effect obliterated by weather in a very short period. The colored brick style, when the buildings are new, gives certainly a variety to our town architecture, and does not there clash with the sense of association; but it quickly loses its effect. In this country, on the other hand, the style is an anomaly, not harmonizing with the color or with the sentiment of the landscape. The value to us of the introduction of this style is for interiors, where it can be treated more delicately without danger of losing its effect so soon; though even here it needs to be handled with a delicacy and refinement, in regard to choice and arrangement of tone, too often absent.

The genuine brick style, what we before called the moulded brick style, is that which has naturally and of necessity been developed in countries where the builders were obliged to trust to this as the only material available in any large quantities for realizing their designs. Like the timber style of Norway, the brick style of Pomerania and some other regions of northern Europe, is the genuine outgrowth of the necessities of the case. It is the attempt to do in brickwork what in other countries other Mediæval workmen accomplished in the grander and more plastic material, stone. And few things in the history of architecture are more interesting and more characteristic than the monuments left by builders contending with restricted materials, but determined to produce with these what effect they can. Like all styles formed in this natural and unaffected manner, the brick architecture of northern Europe is marked by a character at the same time distinct and homogeneous, and directly the result of the peculiarities of the material. Imitated in stone, the features of such a building as the Marien Kirche at Stralsund would appear for the most part anything but attractive; its unadorned spaces of wall would be bare and cold, its ornamental features thin, wiry, and starved looking. Recognize, however, the character and limitations of the material, and all this is changed, and the design comes out as a suitable effect and picturesque achievement. Nothing could more forcibly illustrate the relative nature of architectural design, and the extent to which the intellectual capacity, the reason, is appealed to by it, as well as the eye. It is noticeable, too, that the satisfactory effect fails where the material is strained to do what it cannot satisfactorily accomplish, as in the effort to build up long lines of mullion in such a material as moulded brick. Conversely, the long pilasters, the square turrets and pinnacles in the Pomeranian brick style, which in that style appear as a satisfactory and characteristic treatment, would, if carried out in stone, appear simply bald, the material being capable of so much more rich and free treatment.

Regarding this last as the true brick architectural style, in which the material is made use of to produce purely architectural effects of composition, surface ornament, and light and shade, through the means of moulding and arcading, but with its own peculiar manner suited to the exigencies of the material; the question then becomes, how far is it desirable, in a country where there is no lack of good average building stone, to carry out and enlarge upon a style which in reality expresses the absence of stone, and only came into existence on account of that absence? If anything like

an imitation of the North German style were attempted, it would almost certainly be a failure; for it would be a deliberate putting of himself into fetters by the architect, who should be content to use an inferior and cumbrous material when he had better ready to his hand. Among our stone-yielding districts a building dependent entirely on brick is an anomaly. On the other hand, what we do learn from this brick architecture, among other things, is the value of homogeneous material and treatment, rather than patchwork of a better and a worse material. Brick architecture should be purely brick, architecturally speaking, and aim at brick effects and treatment, and not be dependent on extraneous stone features to make it pass for architecture. And where circumstances are such that it really will enable us to realize an architectural effect and feeling more economically than stone, as in neighborhoods where the stone of the district is poor or in small quantities, there will really be a valid reason for employing the artifical material; for there can be no doubt that as a mere material, in regard to tone and color, and even finish and durability in mouldings and ornaments, good brick is better than a soft and inferior stone. Such cases, however, are exceptional in this country; otherwise, a development of pure brick architecture here must be the result of a wish to obtain a new source of effect, something which our more usual ornamental building materials cannot realize. That this is possible with brick there is no doubt; but not economically; any brick building, to realize architectural effect of a high order, is likely to cost as much, or more, in time and workmanship, if not in material, as stone. Whether it is worth while to try experiments of this kind will depend entirely upon the way in which architecture is regarded. If we preserve the utilitarian theory, and regard a building as a necessary erection, to be set up of the most suitable and procurable materials, and with them made to look as picturesque as possible, brickwork can only retain its place in the very plain class of buildings it has hitherto chiefly been used for; anything beyond that will be best built of stone. If we regard architecture more as an ornamental art, in which we can take any material we like, and fashion it to suit our tastes, that is another thing, and it may be an interesting experiment; but the cases in which this view can be acted upon are not many; public architecture is for the most part indissolubly bound up with public economy, and experiments therein cannot be honestly or successfully made, to any but a very limited extent.

Where brickwork is to be used in architectural design, however, it must be observed that at present we are, in a second sense, in the position of "Israel in Egypt;" for "there is no straw given unto us,"—the material for the highest class of brickwork is not forthcoming; and even the need of a larger or a smaller brick than ordinary, for special purposes, requires something little short of an act of Parliament to produce the article.

Perhaps a little experimentalizing in brick design might at all events have the good effect of forcing our brick manufacturers a little out of their usual groove, and helping to demonstrate that there are more ways than one of using a material of this kind.

THE DRYING OF SEWAGE DEPOSITS.

From "The Building News."

The treatment of sewage may well be said to be one of the chief engineering questions of the day. We have this important subject forced upon us in countless different ways, and there can be but little doubt that, in another session or two at the utmost, Parliament will have to take the matter into consideration. The present state of what is well termed "the sewage question," can be very readily and briefly explained, and the more important difficulties the solution of it presents to us, enumerated. If we assume, as a starting-point, the necessity of water carriage, and make water the vehicle for the removal of fecal matters, we must purify this water, or remove from it, to a great extent, the substances by which it has been polluted, before discharging it into any stream or river. The recommendations of the Royal Commissioners appointed to inquire into the pollution of rivers, are absolute upon this point,

and there can be no possibility of doubt that, in a few years at most, it will be illegal to discharge impure water into any river. A certain standard has been adopted by the Commissioners, and liquids transgressing this standard are deemed inadmissible into potable water. The attainment of the degree of purity set forth in this standard, in an economical way, will be the solution of the sewage question.

It is not necessary that we should here quote the regulations of the Commissioners; they have been drawn up after a most searching investigation into every possible mode of pollution, whether arising from the discharge of town sewage, or the far more dangerous polluting matters from our various manufactories. An investigation extending over seven years, and including the mineral pollution of Cornish mining streams, the cloth-works pollution of the Gloucestershire valleys; that resulting from the waste matters discharged from paper-mills, calico-mills, dye-works, and tanneries; the refuse from distilleries, cotton and woollen manufactories, and iron-works, and, in short, from every industry extant which gives rise to the production of liquid refuse. That water, however grossly it may have been polluted, may again be purified, has been repeatedly proved. Simple filtration through some six feet of soil, will, if the volume of water passing through the filters be carefully regulated, make the filthiest water clear, if not pure again; and this simple mode of dealing with sewage is at present the only one we know of which renders the effluent water pure enough to pass muster before the Rivers' Pollution Commissioners.

But filtration is not an economical mode of treating polluted waters; on the contrary, it is a most costly plan of solving the sewage question, and one that can never be undertaken by itself to deal with large volumes of sewage. If, however, instead of using our land as a simple filter-bed, we greatly extend the area of our operations, and make the surface into a farm, we shall at any rate get some return for our labor in the value of the produce we may be thus enabled to raise; and as, moreover, sewage water contains many valuable manurial ingredients, we may thus expect to get some additional profits from the materials we are dealing with. The land will, in fact, command a higher rent than it would for ordinary agricultural purposes. But for ordinary farming operations, we cannot arrange to have water flowing over and through the soil at all times of the year. For cereals, this would never answer; and in the winter, in time of frost, we could purify no water at all. Where it becomes necessary, therefore, to receive and treat large daily volumes of water throughout the year, sewage-farming is a failure commercially; though, where the quantity of water received is optional, and the rent is low, sewage-farming ought to be made to pay.

We have spoken above of the manurial value of sewage water; this value lies, of course, in its fecal ingredients. Of the valuable matters in sewage, those constituting one-eighth of the whole value are present in a state of suspension, and the remaining seven-eighths are in solution. Now matters in suspension, which constitute about one-half of the total impurity in sewage water, can readily be removed by precipitation; and sewage water so treated loses all, or nearly all, its apparent filthiness, and to the eye becomes bright and pure. If what appeared pleasant to the eye was the only test required for the admission of sewage into potable waters, those who hold to the various precipitation processes would have it all their own way. As we have, however, seen, little more than one-eighth of the total amount of polluting matters, or those having a manurial value, can be removed by this means. The remainder of the matters in suspension are harmless. Strange to say, with this fact staring them in the face, sewage-doctors have been bold enough to assert that not only could they make sewage-water quite pure by means of precipitation, but that out of the matters they thus obtained, they could prepare valuable manures; so valuable, indeed, as to pay the cost of treatment, and return a good margin of profit into the bargain. There are, in fact, enthusiasts still among us who believe in a profit thus accruing, and have risked their money to secure it. We have now to inquire into the materials used in precipitating sewage; we have only to point out that these are the tenets of one school of sewage-doctors, viz., that you may thus purify the sewage, and obtain out of it a profit by the sale of the so obtained manures.

We may point out here that for all methods of dealing with the water, by putting it over or through soil, a previous precipitation and defecation in tanks is a most

valuable antecedent process, and was, indeed, insisted on in the case of the Birmingham Sewage Bill. Not only does less land suffice to deal with a given quantity of sewage under these conditions, but the clogging or choking of the pores by the suspended matter must be reduced to a minimum. Another plan, which had been put forward for the treatment of sewage, is the employment of filters composed of substances useful in themselves as manures, which, when they had done their work, might be sold with considerably increased value as manures. The fatal objection to this plan is the enormous area of the filtering bed required to disinfect the sewage of a populous town, and the great expense of the process. The only other precipitation plan is that advocated by General Scott, who employs the cheapest precipitants—lime and clay— and, disregarding entirely the manure question, burns the deposit into a cement.

In all processes for treating sewage by means of precipitation, the same difficulty crops up, viz., that of drying the sludge, and if we admit that, whether the liquid sewage is to be put on to land, or whether it is to be turned into a running stream at once, it must be previously defecated, we still find we are met by the same question: How can we cheaply and inoffensively dry the deposited sludge? We find in a contemporary, invitations to inventors to communicate their inventions bearing upon this point; and before attempting to solve the question, it may be as well to glance at what we know of its difficulties. The deposits resulting from a precipitation of sewage, whether by lime, sulphate of alumina, sulphate of iron, or phosphate of lime and alumina, which are among the chief materials which have been proposed for the purpose, differ but little as respects their powers of retaining moisture. There are already in several of our manufactures instances where substances have to be recovered in a dry state, after mixture with very large quantities of water. Thus in the manufacture of pottery or porcelain, and, in fact, of all the finer descriptions of clayware, the clays are first reduced to a very liquid mixture, and the water thus used has to be subsequently expelled. In the manufacture of Portland cement, the chalk and clay are incorporated in a wash-mill with large excess of water. In paper manufacture, the pulp, and, in artificial fuel manufacture, the peat, have each to undergo an admixture with enormous volumes of water. In starch manufacture, the starch has to be separated from the gluten in a very liquid mixture. In the manufacture of salt again from brine, and in some dozen processes we might enumerate, the difficulty of expelling a large proportion of water has to be met and grappled with, and all these processes have from time to time furnished by analogy suggestions more or less valuable to the manufacturer who has to deal with sewage sludge. The main difficulty in his case is the low value of the compound he has finally to obtain, the great tenacity with which the water is retained, and the complex nature of the materials he is dealing with. A gallon, or 70,000 grains, of average sewage contains, let us assume, for instance, 125 grains of impurities. On treating this sewage with 15 grains of lime (as the cheapest precipitant), we obtain a precipitation which, when it has settled, and the water has been expelled, will amount to 70 grains, or only one-thousandth part. The other half of the impurities being carried away in the effluent water.

We have, therefore, theoretically to deal with a thousand tons, or 224,000 gallons of such sewage in order to obtain one ton of dry solid extract. In practice the amount would be even larger, as we cannot retain in tanks the whole of the precipitate, and it cannot be entirely deprived of its water. Let us assume now, that, having treated a thousand tons of sewage with the requisite quantity of lime, the precipitate has been formed, and the mixture has been run into a tank; in an hour's time the sewage will become fairly clear, and the solid suspended matters will have sunk to the bottom. By means of a falling penstock, or some similar contrivances, ninety-nine hundredths of the water may be run off in a clarified state, leaving at the bottom a slimy mud, which will be found, on analysis, to consist of 90 parts of water, or, say 9 tons of water and one ton of solid matter. Now begins the real difficulty. How are we to get rid of this water quickly and cheaply? A clay manufacturer of the old school would say, build a slip kiln, *i. e.*, a long shallow evaporating pan, and drive off the moisture by means of hot flues. Well, this can be done; but we are dealing, not with clay, but with a substance much more retentive of moisture, and capable of giving

off a highly unpleasant smell if the heat is not carefully managed. A Staffordshire manufacturer would recommend us to employ the clay presses, in favor of which he has entirely abandoned the use of slip kilns; but our sludge is frequently very corrosive, and destroys the cloths used to press it through. Moreover, we want, if we are making a manure, to drive off 75 per cent. of the water in the sludge, and the clay press will not, at any pressure we can safely employ, expel more than 40 to 50 per cent. We cannot send out the sludge in a semi-dry state. To shorten our description of the means that have been suggested for drying sludge, we may mention the centrifugal wringer, which would, it was supposed, drive off the water, and leave the suspended impurities in the machine. This plan of drying has, we think, many advantages, and requires more careful trial than it has hitherto received. The danger consists in the choking of the pores of the wringer by the semi-solidified sludge, which quickly forms cakes wholly impervious to water. Another plan proposed is the exhaustion of the air in cylinders covered with canvas, over which the sludge is caused to flow, and this plan has, we think, a fair chance of success. Messrs. Milburn have invented a stove consisting of a series of hot plates, upon which a thin layer of sludge is being constantly kept in motion. The only objection to this plan is that up to the present time the cost is very great per ton of the dried sludge; another and similar plan is a machine consisting of an iron cylinder surrounded by heated flues and in the centre of the cylinder the sludge is introduced. As the cylinder is caused slowly to rotate on its axis, the sludge flows and rolls over the heated interior surface, and is rapidly dried. This plan has many advantages, but it has not yet been made to work economically. What is really required is a machine capable of drying say 10 tons of sludge per diem, or bringing 10 tons of the liquid sludge, containing, as we have seen, 90 per cent. of moisture, down to a solid containing but from 10 to 15 per cent. of moisture—and none of the drying-machines we have yet seen can be said to have accomplished this. The cost of completely drying 10 tons of sludge, containing about 2,000 gallons of water, by means of an evaporating floor, ought not to exceed the price of a ton of coal in theory, but in practice the cost is considerably more. To obtain one ton of sludge, containing upwards of 50 per cent. of water, would seem to cost from 4s. to 7s. by the different processes we have examined. Having thus set forth what has been at present done towards the drying of sludge, we must leave the problem to our readers; it is one well worthy of consideration, and its speedy solution is of the utmost importance.

BOLLMAN TRUSS.

By W. ALLAN, McDonogh Institute, Md.

In the January number of VAN NOSTRAND, the error into which Mr. Shreve has inadvertently fallen in calculating the chord strain in the Bollman truss is well set forth by Mr. T. H. Smith; and yet the heading of his article would seem to imply that the question as to the accuracy of his result, and the error of Mr. Shreve's, was still "open."

The method of calculating the chord strain in a Bollman, used by Vose and others and given by Mr. Smith, is the simplest and shortest; but it can be readily shown by using Shreve's method (that of moments), that his error lies in omitting from the equation the strains in the ties cut by the central plane. As Mr. Smith says, the strains in these ties do not neutralize each other; on the contrary, they combine.

Bisecting the loaded truss by a vertical plane, we cut 16 ties—eight of those coming from each end. For convenience, take the centre of moments at the foot of the central post. The two ties passing through this point will, of course, not appear in the equation of moments. Dropping perpendiculars from this centre upon each of the other intersected ties, and either calculating their length or measuring them on a scaled drawing, we find them to be in order (in the example given by Shreve and Smith).

1.657, 2.98, 4.07, 4.99, 5.75, 6.41. 7.00

Each of these perpendiculars applies to ten ties. The points in which these perpendicu-

lars intersect the ties running from the left abutment, for instance, all lie on a circle described on the tie running to the middle post as a diameter.

The strains on the ties, met by the above perpendiculars, are in the same order—

39.92, 37.92, 34.69, 30.22, 24.53, 17.6, 9.42

Multiplying each form by its lever-arm, we have for the moments of the ties—

66.15, 113.00, 141.19, 150 82, 141.07, 112 82, 65 95.

Nor if W = entire load (240 tons) and L = entire length (160 ft.) and D = depth (15 ft.), and S = the unknown horizontal chord strain, the equation of moments taken about the foot of the central post when the truss is fully loaded is

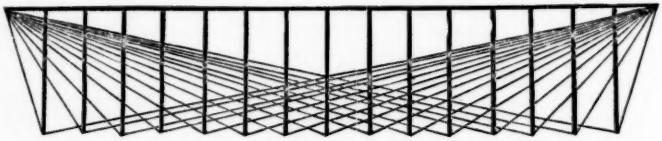
$$\tfrac{1}{2}\,W.\,\tfrac{1}{2}\,L-\tfrac{1}{2}\,W.\,\tfrac{1}{4}\,L$$
$$= S\ D-2\{66\ 15+113.+141.19+150.82+$$
$$141.07+112.82+65\ 95\}=S.\ D-1582.$$

Substituting the values,

$$9600-4800=15.\ S-1582,$$
$$\therefore\ S=\frac{6382}{15}=425+$$

(The slight excess is due to the inexactness of the decimals.)

If I understand Mr. Smith's statement as to the constancy of "work done," when



the "panel data" are the same, he seems to me in error. In a quadrangular truss of the dimensions and load of the Bollman above discussed, the "centre formula," as he calls it, or the formula for moments round a point in the centre of one of the chords when the truss is uniformly loaded, reduces to its simplest form and gives 320 tons for the chord strain in each chord, being tension in one and compression in the other. The chord strain is different, therefore, from that found for the Bollman and the Fink.

NOTES ON SEWAGE.

From "Engineering."

In a previous article we noticed the great difficulties which are presented to all schemes of sewage utilization by the albumenoid constituents of sewage, consequent on their slow decomposition. This fact has most especial reference to the chemical schemes that have been proposed, as it is the oxidation of such albumenoid substances which is an essential condition of success. Consequent on this, irrigation has a great advantage over any other method, for the prolonged action of the oxygen of the air eventually resolves such substances into fresh combinations, that thus become valuable as manure.

All the chemical schemes tend, owing to the employment of an acid sulphate of alumina, to solidify such albumenoids, and so render them less available for immediate use for manurial purposes. In the case of a rich specimen of the so-called Native Guano, it was found that after it was dried, several days elapsed during a daily summer temperature averaging 84 deg. Fahr. in the shade, before ammonia was evolved; while during autumn a similar class of manure might be kept for weeks before the resolution of such albumenoids into ammonia was effected. Hence the chemical analysis of liquids containing sewage contamination presents peculiar difficulties if such albumenoids of the class referred to are present in large quantities. The analysis of human urine gives a special illustration of this difficulty, and, perhaps, from this cause arises the paucity of the analysis of urine that now exists.

The amount of these albumenoidal substances present in a river into which sewage is emptied from adjacent towns, will, of course, depend on the number of the closets emptying themselves into the sewers, the population, the ratio of water supply, and some other causes which have been already

noticed in the preceding articles. In some parts of the kingdom the use of water-closets is discouraged, as far as possible, by the local authorities, on account of a very uncertain and frequently short supply of water. Halifax is an instance of this kind. In such localities Goux's and other processes have been suggested, by means of which all the human excreta, including urine, but excluding waste water previously employed for washing, cooking, etc., are received in vessels containing an absorbent substance, and such vessels are periodically removed and replaced by others. Moule's earth system is admirably adapted for such purposes, and deserves application wherever such is admissible. The fact, however, cannot be concealed, that, at least in the South of England, local prejudices and domestic arrangements render its adoption all but impracticable, but some of its modifications might be followed.

It is remarkable that while a large portion of the North of England, a still larger proportion of the West of Scotland, and nearly one-seventh of the area of Ireland abound in peat, this substance has scarcely been used to be mixed with the excreta of our households. Of course here we do not refer to its natural state, but to the charcoal that may be obtained from it. Peat-charcoal is one of the most porous of all forms of impure carbon. Its powers of absorption, when dry, are very great. In experiments tried on the sewage of Leamington in 1870–71, it was found that two or three ounces of newly made peat-charcoal, obtained from near Bury, in Lancashire, were sufficient to deodorize six gallons of ordinary sewage. The actual proportions employed were about one part of charcoal to one hundred and fifty of sewage by weight. In a few minutes after the charcoal was mixed with the rich albumenoid sewage, a peculiar sweet smell was noticed; but in less than a quarter of an hour all smell had disappeared, and the constant addition of fecal matter did not permanently restore the smell. A closet arranged for the purpose was devoted to the use of 40 laborers, but even during the hot summer of 1870, on no occasion was any offensive smell noticeable, although the amount of peat-charcoal daily employed did not equal the proportion already stated.

We have already pointed out that continuously running sewage, having no hinderance in its progress to its outfall, rarely affords any gases that could be dangerous to health, but that wherever its continuous progress was delayed or stopped, these offensive and dangerous gases were evolved. In an article on "The Sanitary Retrospect of 1872" we have already discussed the effect of the excessive rainfall of that year as resulting in a decrease of mortality in the United Kingdom usually assigned to diseases of the zymotic class. We there suggested a variety of reasons why such a result should have occurred, and also pointed out certain lessons that might be deduced from the experience of November and December in 1872, and of January of the present year. There can be no doubt that the accidental circumstances of that period were highly favorable to public health, despite the fact that the average monthly temperature was about 10 deg. Fahr. beyond that of the preceding years. In fact, all or most of the substances which fall under the denomination of "previous sewage contamination," that is those albumenoid matters which we are now specially discussing, were driven off to the sea, in the majority of cases, in regard to our large towns, and under the general laws of physiological and chemical science, have been, or are now being returned to us in the form of various kinds of fish frequenting our coasts.

The difficulty under which we labor is to define the amount of excremental pollution which may at any time become dangerous in a running stream such as the Thames. It is highly probable in the latter case that a large proportion of the albumenoid or undecomposed nitrogenous matter of animal origin is not decomposed during its progress towards the sources whence some of the London water companies take their supply. Much has lately been said about the disfigurement which would arise near Hampton Court, if the Chelsea Water Works' proposition, to erect a reservoir, were carried into effect. We lately attended a most enthusiastic meeting in which that proposition was denounced as simply a question of the picturesque, but not one word was said in regard to the sanitary aspects of the question. We have before us the reports of two medical officers of health resident in two of our leading inland "Spas," but in neither of these is reference made to the combined question of sewage disposal, or the water supply, although in both cases the latter is contaminated by sewage.

An interesting paper on the determination of this organic nitrogen, by Mr. Wanklyn, appeared in the "Philosophical Magazine" of May, 1872, to which we must refer our scientific readers who wish to appreciate the difficulties we have named, so far as chemical analysis is concerned. Practically, we endeavored to overcome the difficulty by the following experiment; that is, we attempted to arrive at some method by which the nitrogenous matters could be eliminated from a sewage-contaminated river. A series of glass vessels were placed at successive elevations of a foot apart, in such a manner that the water (contaminated highly with sewage, and very offensive in smell) should fall drop by drop from the highest to the lowest, hence each drop passed through about 5 ft. in the open atmosphere. It required, however, to return the liquid four times to the upper vessel before the water became without odor or taste. In other words, besides accidental exposure to the atmosphere, while the liquid rested in each vessel, a fall of 20 ft. was needed, the entire surface of each drop being thus exposed to the oxidizing influence of the atmosphere.

This experiment still left much to be desired when its results were examined by careful chemical analysis. If with all the care that was bestowed on this attempt, resulting in no great benefit, what can be expected of the nature of river water, such as that of the Thames, contaminated with the sewage of scores of towns and villages, manured fields, etc, as a source of water supply for a large portion of the metropolis? Sewage fungus has long, and we believe, justly, been considered as a sign of dangerous conditions in a water supply. Dr. Frankland and many other authorities have endorsed this statement. It is somewhat remarkable that most fungoid growths have more or less inimical relations to human health. Hence, even the ordinary mushroom has frequently poisonous effect. Careful investigations in India during recent years have shown that certain fungoid growths on rice have been accompanied with outbreaks of diarrhœa and the severer forms of Asiatic cholera. The banks of the Thames and the Lea, and at times some parts of the New River, present instances of sewage fungus, especially during August and September. It is especially during these periods that diseases of the choleraic character are most prevalent, a result generally ascribed to the rotting of the weeds growing in such streams. But a little further examination will prove that the concomitant of such rotting is really the production of fungus. Even our trees are thus affected. A young and vigorous sapling never shows sign of fungous growth on its stem, while those of older growth are invariably tainted by it.

A careful chemical analysis of these fungoids discloses the presence of nitrogen; and this points to the fact that the albumenoid matters on which we are now treating may be considered as their source. Between Twickenham and Kew the Thames affords abundance of this growth, but as a rule it ceases beyond Erith to Gravesend, at which latter place sea-water produces new conditions of decomposition. Proceeding up the Thames beyond the limit of the tidal flow, the presence of sewage fungus is readily detected at all times when the river is not in flood, indicating the presence of sewage matter. In fact, for all practically sanitary purposes, the most cursory examination of the grass, etc., lining the banks and drooping into the stream, will be sufficient to indicate the presence of sewage fungus, and concomitantly the utter unfitness of such water for drinking purposes.

Dr. Frankland has justly stated that "sewage and animal excrementitious matters are believed sometimes to contain organic poisons, which when taken into the stomach are capable of producing in the human subject such diseases as cholera and typhoid fever, and yet that such poisons cannot be discovered by chemical analysis. Like the infecting matter of small pox, cow-pox and glanders, and the venom of serpents, they can only be detected by their effects on animals, and more especially on man." It is not our business to discuss physiological or pathological questions, but still both the science and art of engineering must largely depend on the aid which such researches, combined with those of chemical science, afford. The engineer, architect, and ordinary builders are frequently presumed to be in fault, a special case of which was instanced in the case of the supposed causes of the dangerous illness of the Prince of Wales, and the death of Lord Chesterfield. But the real default in these as in perhaps thousands of similar cases, lay in the hands of medical and chemical authorities, rather than in those who had simply the

supervision of the mechanical arrangements for the disposal of sewage.

The action of yeast on flour presents a very simple illustration of the effects of sewage fungus on the human system. Liebig pointed out some years ago an analogous action of the poisonous matter in German sausage, and possibly what is called *mussel-poisoning* may belong to the same category. To be practical, the engineer has no resource but that of using the best of his experience to get rid, as quick as possible, of the matters we have treated on in this article. Hitherto the profession has been almost neglected in this matter with respect to sanitary results; in fact they have been chiefly intrusted to patch up the defects of theories that have been applied at the suggestion of other professions. As Horace saith, if you can find a better plan we will adopt it; if not, we must still hold to our own. Perhaps our readers will pardon this free translation of a well-known remark made by that eminent Roman poet; it is apposite to our position.

SCIENCE AND PRACTICE IN TELEGRAPHIC ENGINEERING.*

Engineering may be defined as the application of practical science to man's material circumstances and means of action. As usual in classification, the nomenclature of branches of engineering is full of what the logician calls cross-divisions. Thus we have civil and military engineering, and again, civil and mechanical engineering; then architecture and building, engineering and contracting. We have, it is true, in the distinction between military and civil engineering a good logical division. Every subject of civil engineering is included in military engineering, because an army has all the wants of any large body of civilians. But military engineering includes more, because there is no civil purpose which requires rifled cannon, shot and shell, hand-grenades, torpedoes, iron-clads, armed fortications, mining under fire or under liability to hand-to-hand encounter with an enemy, and field telegraphs. I have enumerated all the subjects which I can think of that belong exclusively to military engineering, and, except these, all subjects of general engineering are embraced in civil engineering, properly so called. The division between military and civil engineering is, therefore, not properly founded on a distinction in respect to the subject matter, but it is a true logical division in respect to the province of application. Now remark the division between civil and mechanical engineering—a distinction habitually used, as if the engineering of merchant steamers, of cotton mills, of sugar machinery, of calico printing, of letter-press printing, were not truly parts of civil engineering. I make no complaint of the ordinary language which designates as civil engineering only that which is neither military, nor concerned with mechanism otherwise than in designing and testing it, and which calls mechanical engineering the construction, daily use, and maintenance of machines. I make no complaint of the ordinary language which so designates civil engineering, and distinguishes it from mechanical engineering. I only say that it is not logical. Take, again, architecture. Architecture is not commonly called a branch of engineering at all. I think it unfortunate that the public do not regard architecture as a branch of engineering. When architects come to regard themselves as engineers, and when the public come to expect them to act as engineers, let us hope they will give us buildings not less beautiful and not less interestingly connected with monuments and traditions of beauty from bygone ages than they give us now. But assuredly there will then be less typhoid fever. Then invalids too ill to walk, or ride, or drive out of doors, or to be benefited by the beautiful scenery of Mentono, or Corsica, or Madeira, will not be expatriated merely to avoid the evil effects of the indoor atmosphere of England. Then people in good health will not be stupefied by a few hours of an evening at home in gaslight, or of social reunion, or by one hour of a crowded popular lecture or meeting of a learned society. Then in our hotels, and dwelling-houses, and clubs, we shall escape the negatively refreshing influence of the all-pervading daily aerial telegraph, which prematurely transmits intelligence of distant and future dinners. The

* Abstract from the address of Sir William Thompson before the Society of Telegraph Engineers.

problem of giving us within doors any prescribed degree of temperature, with air as fresh and pure as the atmosphere outside the house can supply, may be not an easy problem; but it is certainly a problem to be solved when architecture becomes a branch of scientific engineering. Now as to the relations between theory and practice in telegraphic engineering, I feel that I have more to say respecting the reflected benefits which electrical science gains from its practical applications in the electric telegraph, than of the value of theory in directing, and aiding, and interesting the operators in every department of the work of the electric telegraph. In no other branch of engineering, indeed, is high science more intelligently appreciated and ably applied than in the manufacture and the use of telegrapic lines, whether over land or under sea; and it would be quite superfluous for me to speak on that subject to those whom I see before me. But I do not know whether so much is thought of what the electric telegraph and its workers have already done, and may be expected yet to do, for science in general, and particularly electricity and magnetism. Time does not allow me to enlarge, as I would like to do, on this subject. I will merely remind those who are present of the great advance that has been made in accurate measurement within the last fifteen years. I need not tell you that a large part of the benefit thus achieved for science is due to the requirements of the practical telegraphist. Men of abstract science were satisfied to know that absolute measurement was possible, and that a definition of magnetic force, a definition of electric resistance, a definition of electromotive force, and so on through the list of numerical quantities in electricity, could each of them be defined in absolute measure. We owe to Gauss and Weber the first great practical realization in abstract science of a system of absolute measurement; but their principles did not extend rapidly even in the domains of abstract science where their theory was well understood, because the urgent need for its practical application was not felt. When accurate measurement in any definite unit first became prevalent was when it was required by the electric telegraph. The pioneers of science, many of whom, happily for us, still work for science and for the electric telegraph, laid down various perfectly definite units for the measurement of electric resistance—that most primary one of the various subjects for measurement. I need not remind any of you of the history of electric units of resistance, or of the labors of the Committee of the British Association to bring that system of measurement into harmony with the theoretical definitions of Gauss and Weber. The benefits conferred by introducing a system of definite measurement into the working of the electric telegraph are due not solely—perhaps not even in chief—to the application of Gauss's system, but to the introduction of very accurate and definite standards of resistance and means of reproducing those standards should the originals be lost. The benefit of putting the practical standards into relation with the science of Gauss and Weber has been set forth in the successive reports of the Committee of the British Association on electric measurement, and is well known, I believe, to most of the members of the Society of Telegraph Engineers. But now what I wish to say is, that theoretical science has gained great reflective benefit from the introduction of accurate measurement of resistance into practical telegraphy. For many years the measurements were performed in the office of the telegraph factory, and at the station-house of the telegraphic wire, the means of doing it, possibly—perhaps I might even say the principles on which those measurements were conducted — being still unknown throughout the scientific laboratories of Europe. The professors of science who threw out the general principle have gained a rich harvest for the seed which they sowed. They have now got back from the practical telegrapher accurate standards of measurement, and ready means of transmitting those standards and of preserving them for years and years without change, which have proved of the most extreme value to the work of the scientific laboratory. I might make similar remarks regarding electric instruments. The theory of electric instruments has been taught by those who have labored in theoretical science, but the zeal and ability with which the makers and users of instruments in the service of the electric telegraph have taken up the hints of science have given back to the scientific laboratory instruments of incalculable value. But I wish rather to confine myself to looking forward to the benefits which science may derive from its practical applications in telegraph engi-

neering, and to point out that this Society is designed by its founders to be a channel through which these benefits may flow back to science, and, on the other hand, to supply the counter-channels by which pure science may exercise its perennially beneficial influence on practice. Time would fail me to give any such statement as would include a large part of the subject upon which I have touched; I shall therefore confine myself strictly to one point, and that is the science of terrestrial electricity. I have advisedly, not thoughtlessly, used the expression "terrestrial electricity." It is not an expression we are accustomed to. We are accustomed to "terrestrial magnetism;" we are accustomed to "atmospheric electricity." The electric telegraph forces us to combine our ideas with reference to terrestrial magnetism and atmospheric electricity. We must look upon the earth and the air as a whole—a globe of earth and air—and consider its electricity whether at rest or in motion. Then, as to terrestrial magnetism, what its relation may be to perceptible electric manifestations we at present know nothing. You all know that the earth acts as a great magnet. Dr. Gilbert, of Colchester, made that clear nearly 300 years ago; but how the earth acts as a great magnet—how it is a magnet, whether an electro-magnet in virtue of currents revolving round under the upper surface, or whether it is a magnet like a mass of steel or loadstone, we do not know. This we do know, that it is a variable magnet, and that a first approximation to the variation consists in a statement of motion round the axis of figure—motion of the magnetic poles, round the axis of figure, in a period of from 900 to 1000 years. The earth is not a uniformly magnetized magnet with two poles, and with circles of symmetry round those poles. But a first expression —as we should say in mathematical language, the first "harmonic term"—in the full expression of terrestrial magnetism is an expression of a regular and symmetrical distribution such as I have indicated. Now, this is quite certain, that the axis of this first term, so to speak, or this first approximation, which, in fact, we might call the magnetic axis of the earth, does revolve round the axis of figure. When the phenomena of terrestrial magnetism were first somewhat accurately observed about three hundred years ago, the needle pointed here in England a little to the east of north; a few years later it pointed due north; then, until about the year 1820, it went to the west of north; and now it has come back towards the north. The dip has experienced corresponding variations. The dip was first discovered by the instrument maker, Robert Norman, an illustration, I may mention in passing, of the benefits which abstract science derives from practical applications—one of the most important fundamental discoveries of magnetism brought back to theory by an instrument maker who made mariner's compasses. Robert Norman, in balancing his compass-cards, noticed that after they were electrified one end dipped, and he examined the phenomenon and supported a needle about the centre of gravity, magnetized it, and discovered the dip. Well, when the dip was first so discovered by Robert Norman it was less than it is now. The dip has gone on increasing, and is still increasing, although the diviation from true north is greatest. Everything goes on as if we had a pole which was distant from us on the far side of the pole of figure—what we commonly call the north pole—a magnetic pole first on the far side of the north pole. About three hundred years ago it was a little to the east of the north pole; then it came round, as we look at the north pole, eastward, and towards us, so as to describe a circle on the left-hand side of the pole, and back between us and the north pole towards the magnetic pole. That motion in a circle round the pole has already been experienced within the period during which accurate measurements have been made—has been experienced to the extent of rather more than a quarter of the pole revolution. It is one of the greatest mysteries of science, a mystery which I might almost say is to myself a subject of daily contemplation—what can be the cause of this magnetism in the interior of the earth? Rigid magnetization, like that of steel or the loadstone, has no quality in itself in virtue of which we can conceive it to migrate round in the magnetized bar. Electric currents afford the more favorable hypothesis; they are more mobile. If we can conceive electric currents at all, we may conceive them flitting about. But what sustains the electric currents? People sometimes say, heedlessly or ignorantly, that thermo-electricity does it. We have none of the elements of the problem of thermo-electricity in the state of underground temperature which could

possibly explain, in accordance with any knowledge we have of thermo-electricity, how there could be sustained currents round the earth. And if there were currents round the earth, regulated by some cause so as to give them a definite direction at one time, we are as far as ever from explaining how the channel of those currents could experience that great secular variation which we know it does. Then we have merely a mystery. It would be rash to suggest even an explanation. I may say that one explanation has been suggested. It was suggested by the great astronomer, Halley, that there is a nucleus in the interior of the earth, and that the mystery is explained simply by a magnet not rigidly connected with the upper crust of the earth, but revolving round an axis differing from the axis of figure of the outer crust, and exhibiting a gradual precessional motion independent of the precessional motion of the outer rigid crust. I merely say that has been suggested. I do not ask you to judge of the probability: I would not ask myself to judge of the probability of it. No other explanation has been suggested. But now, I say, we look with hopefulness to the practical telegraphist for data towards a solution of this grand problem. The terrestrial magnetism is subject, as a whole, to the grand secular variation which I have indicated. But, besides that, there are annual variations and diurnal variations. Every day the needle varies from a few minutes on one side to a few minutes on the other side of its mean position, and at times there are much greater variations. What are called "magnetic storms" are of not very unfrequent occurrence. In a magnetic storm the needle will often fly twenty minutes, thirty minutes, a degree, or even as much as two or three degrees sometimes, from its proper position—if I may use that term—its proper position for the time; that is, the position which it might be expected to have at the time according to the statistics of previous observations. I speak of the needle in general. The ordinary observation of the horizontal needle shows these phenomena. So does observation on the dip of the needle. So does observation on the total intensity of the terrestrial magnetic force. The three elements, deflection, dip, and total intensity, all vary every day with the ordinary diurnal variation, and irregularly with the magnetic storm. The magnetic storm is always associated with a visible phenomenon, which we call, habitually, electrical. I mean aurora borealis, and I have no doubt, also, aurora of the southern polar regions. We have the strongest possible reasons for believing that aurora consists of electric currents, like the electric phenomena presented by currents of electricity through what are called vacuum tubes, through the space occupied by vacua of different qualities in the well known vacuum tubes. Of course, the very expression, "vacua of different qualities," is a contradiction in terms. It implies that there are small quantities of matter of different kinds left in those nearest approaches to a perfect vacuum which we can make. Well, now, it is known to you all that aurora borealis is properly comparable with the phenomena presented by vacuum tubes. The appearance of the light, the variations which it presents, and the magnetic accompaniments, are all confirmatory of this view, so that we may accept it as one of the truths of science. Well, now—and here is a point upon which, I think, the practical telegraphist not only can, but will, before long give to abstract science data for judging—is the deflection of the needle a direct effect of the auroral current, or are the auroral current and the deflection of the needle common results of another cause? With reference to this point, I must speak of underground currents. There again I have named a household word to everyone who has anything to do with the operation of working the electric telegraph, and not a very pleasing household word I must say. I am sure most practical telegraphers would rather never hear of earth currents again. Still we have got earth currents; let us make the best of them. They are always with us; let us see whether we cannot make something out of them since they have given us so much trouble. Now, if we could have simultaneous observations of the underground currents, of the three magnetic elements, and of the aurora, we should have a mass of evidence from which, I believe, without fail, we ought to be able to conclude an answer more or less definite to the question I have put. Are we to look, then, in the regions external to our atmosphere for the cause of the underground currents, or are we to look under the earth for some unknown cause affecting terrestrial magnetism, and giving rise to an induction of

those cnrrents? The direction of the effects, if we can only observe those directions, will help us most materially to judge as to what answer should be given. It is my desire to make a suggestion which may reach members of this Society, and associates in distant parts of the earth. I make it not merely to occupy a little time in an inaugural address, but with the most earnest desire and expectation that something may be done in the direction of my suggestion. I do not venture to say that something may come from my suggestion, because, perhaps, without any suggestion from me, the acute and intelligent operators whom our great submarine telegraph companies have spread far and wide over the earth, are fully alive to the importance of such observations as I am now speaking of. I would just briefly say that this kind of observation is what would be of value for the scientific problem—to observe the indication of an electrometer at each end of a telegraph line at any time, whether during a magnetic storm or not, and at any time of the night or day. If the line be worked with a condenser at each end, this observation can be made without in the slightest degree influencing, and therefore without in the slightest degree disturbing, the practical work throughout the line. Put on an electrometer in direct connection with the line, connect the outside of the electrometer with a proper earth connection, and it may be observed quite irrespectively of the signalling; when the signalling is done, as it very frequently is at submarine lines, with a condenser at each end. The scientific observation will be disturbed undoubtedly, and considerably disturbed by the sending of messages, but the disturbance is only transient, and in the very pause at the end of a word there will be a sufficiently near approach in the potential at the end of the wire connected with the electrometer to allow a careful observer to estimate with practical accuracy the indication that he would have were there no working of the line going on at the time. A magnetic storm of considerable intensity does not stop the working, does, indeed, scarcely interfere with the working of a submarine line, in many instances, when a condenser is used at each end. Thus, observations, even when the line is working, may be made during magnetic storms, and again, during hours when the line is not working, if there are any, and even the very busiest lines have occasional hours of rest. Perhaps, then, however, the operators have no time or zeal left, or, rather, I am sure they have always zeal, but I am not sure that there is always time left, and it may be impossible for them to bear the strain longer than their officials require them. But when there is an operator, or a superintendent, or a mechanic, or an extra operator, who may have a little time on his hands, then, I say, any single observation, or any series of observations that he can make on the electric potentials at one end of an insulated line will give valuable results. When arrangements can be made for simultaneous observations of the potentials by an electrometer at the two ends of the line, the results will be still more valuable. And, lastly, I may just say that when an electrometer is not available, a galvanometer of very large resistance may be employed. This will not in the slightest degree interfere with the practical working any more than would an electrometer, but it will be more difficult to get results of the scientific observations not overpoweringly disturbed by the practical working, if a galvanometer is used than when an electrometer is available. Still, where there is no electrometer, valuable results may be obtained by applying a galvanometer in the manner I have indicated. The more resistance that can be put in between the cable and the earth in circuit with a galvanometer the better, and the sensibility of the galvanometer will still be found perhaps more than necessary. Then, instead of reducing it by a shunt, let steel magnets giving a more powerful direction to the needle be applied for adjusting it. I should speak also of the subject of atmospheric electricity. The electric telegraph brings this phenomenon into connection with terrestrial magnetism with earth currents, and through them with aurora borealis, in a manner for which observations made before the time of the electric telegraph, or without the aid of the electric telegraph, have not given us any data whatever. Scientific observations on terrestrial magnetism, and on the aurora, and on atmospheric electricity, have shown a connection between the aurora and terrestrial magnetism in the shape of the disturbances that I have alluded to at the time of magnetic storms; but no connection between atmospheric electricity, thun-

derstorms, or generally the state of the weather—what is commonly called meteorology—has yet been discovered. There is just one common link connecting these phenomena and those exhibited in the electric telegraph. A telegraphic line—an air line more particularly, but a submarine line also—shows us unusully great disturbances not only when there are aurora and variations of terrestrial magnetism, but when the atmospheric electricity is in a disturbed state. That it should be so, electricians here present will readily understand. They will understand when they consider the change of electrification of the earth's surface which a lightning discharge necessarily produces. I fear I might occupy too much of your time, or else I would just like to say a word upon atmospheric electricity, and to call your attention to the quantitative relations which questions in connection with this subject bear to those of ordinary earth currents and the phenomena of terrestrial magnetism. In fair weather, the surface of the earth is always, in these countries at all events, found negatively electrified. Now the limitation to these countries that I have made, suggests a point for the practical telegraphists all over the world. Let us know whether it is only in England, France, and Italy that in fine weather the earth's surface is negatively electrified. The only case of exception on record to this statement is Professor Piazzi Smyth's observations on the Peak of Teneriffe. There, during several months of perfectly fair weather, the surface of the mountain was, if the electric test applied was correct, positively electrified; but Professor Piazzi Smyth has, I believe, pointed out that the observations must not be relied upon. The instrument, he found himself, was not satisfactory. The science of observing the atmospheric electricity was then so much in its infancy that, though he went prepared with the best instrument, and the only existing rules for using it, there was a fatal doubt as to whether the electricity was positive or negative after all. But the fact that there has been such a doubt is important. Now I suppose there will be a telegraph to Teneriffe before long, and then I hope and trust some of the operators will find time to climb the Peak. I am sure that, even without an electric object, they will go up the Peak. Now, they must go up the Peak with an electrometer in fine weather, and ascertain whether the earth is positively or negatively electrified. If they find that on one fine day it is negatively electrified, the result will be valuable to science; and if on several days it is found to be all day and all night negatively electrified, then there will be a very great accession to our knowledge regarding atmospheric electricity. When I say the surface of the earth is negatively electrified, I make a statement which I believe was due originally to Peltier. The more common form of statement is that the air is positively electrified, but this form of statement is apt to be delusive. More than that, it is most delusive in many published treatises, both in books and encyclopædias, upon the subject. I have in my mind one encyclopædia, in which, in the article "Air, electricity of," it is said that the electricity of the air is positive, and increases in rising from the ground. In the same encyclopædia, in the article "Electricity, atmospheric," it is stated that the surface of the earth is negatively electrified, and that the air in contact with the earth, and for some height above the earth, is, in general, negatively electrified. I do not say too much, then, when I say that the statement that the air is positively electrified has been at all events a subject for ambiguous and contradictory propositions; in fact, what we know by direct observation is, that the surface of the earth is negatively electrified, and positive electrification of the air is merely inferential. Suppose, for a moment, that there were no electricity whatever in the air—that the air were absolutely devoid of all electric manifestation, and that a charge of electricity were given to the whole earth. For this no great amount would be necessary. Such amounts as you deal with in your great submarine cables would, if given to the earth as a whole, produce a very considerable electrification of its whole surface. You all know the comparison between the electricity of one Atlantic cable—the electro-static capacity of one of the Atlantic cables—with the water round its gutta-percha for outer coating, and the earth and air with infinite space for its outer coating. I do not remember the figures at this moment; in fact, I do not remember which is the greater. Well, now, if all space were non-conducting—and experiments on vacuum tubes seem rather to support the possibility of that being the correct view—if all space were non-conducting, our atmos-

phere being a non-conductor, and the rarer and rarer air above us being a non-conductor, and the so-called vacuous space, or the interplanetary space beyond that (which we cannot admit to be really vacuous) being a con-conductor also, then a charge could be given to the earth as a whole, if there were the other body to come and go away again, just as a charge could be given to a pith ball electrified in the air of this room. Then, I say, all the phenomena brought to light by atmospheric electrometers, which we observe on a fine day, would be observed just as they are. The ordinary observation of atmospheric electricity would give just the result that we obtain from it. The result that we obtain every day in observations on atmospheric electricity is precisely the same as if the earth were electrified negatively and the air had no electricity in it whatever.

Well, now, I have asserted strongly that the lower regions of the air are negatively electrified. On what foundation is this assertion made? Simply by observation. It is a matter of fact; it is not a matter of speculation. I find that when air is drawn into a room from the outside, on a fine day, it is negatively electrified. I believe the same phenomena will be observed in this city as in the old buildings of the University of Glasgow, in the middle of a very densely peopled and smoky part of Glasgow; and therefore I doubt not that when air is drawn into this room from the outside, and a water-dropping collector is placed in the centre of the room, or a few feet above the floor, and put in connection with a sufficiently delicate electrometer, it will indicate negative electrification. Take an electric machine; place a spirit-lamp on its prime conductor; turn the machine for a time; take an umbrella, and agitate the air with it till the whole is well mixed up; and keep turning the machine, with the spirit-lamp burning on its prime conductor. Then apply your electric test, and you find the air positively electrified. Again—Let two rooms, with a door and passage between them, be used for the experiment. First shut the door and open the window in your observing room. Then, whatever electric operations you may have been performing, after a short time you find indications of negative electrification of the air. Then, during all that time, let us suppose that an electric machine has been turned in the neighboring room, and a spirit-lamp burning on its prime conductor. Keep turning the electric machine in the neighboring room, with the spirit-lamp as before. Make no other difference but this — shut the window and open the door. I am supposing that there is a fire in your experimenting room. Then, when the window was open and the door closed, the fire drew its air from the window, and you got the air from without. Now shut the window and open the door into the next room, and gradually the electric manifestation changes. And here somebody may suggest that it is changed because of the opening of the door and the inductive effect from the passage. But I have anticipated that observation by saying that my observation has told me that the change takes place gradually. For a while after the door is opened and the window closed, the electrification of the air in your experimental chamber continues negative, but it gradually becomes zero, and a little later becomes positive. It remains positive as long as you keep turning the electric machine in the other room and the door is open. If you stop turning the electric machine, then, after a considerable time the manifestation changes once more to negative; or if you shut the door and open the window, the manifestation changes more rapidly to negative. It is, then, proved beyond all doubt that the electricity which comes in at the windows of an ordinary room in town is ordinarily negative in fair weather. It is not always negative, however. I have found it positive on some days. In broken weather, rainy weather, and so on, it is sometimes positive and sometimes negative. Now, hitherto there is no proof of positive electricity in the air at all in fine weather; but we have grounds for inferring that probably there is positive electricity in the upper regions of the air. To answer that question, the direct manner is to go up in a balloon; but that takes us beyond telegraphic regions, and therefore I must say nothing on that point. But I do say that superintendents and telegraph operators in various stations might sometimes make observations; and I do hope that the companies will so arrange their work, and provide such means for their spending their spare time, that each telegraph-station may be a sub-section of the Society of Telegraph Engineers, and may be able to have meetings, and make experiments, and put their forces together to endeavor to arrive at the truth. If tele-

graph operators would repeat such experiments in various parts of the world, they would give us most valuable information. And we may hope that besides definite information regarding atmospheric electricity, in which we are at present so very deficient, we shall also get towards that great mystery of nature—the explanation of terrestrial magnetism and its associated phenomena of the grand secular variation of magnetism, magnetic storms, and the aurora borealis.

And now, gentlemen, I must apologize to you for having trespassed so long upon your time. I have introduced a subject which, perhaps, more properly ought to have been brought forward as a communication at one of the ordinary meetings. I may just say, before sitting down, that I look forward with great hopefulness to the future of the Society of Telegraph Engineers. I look upon it as a Society for establishing harmony between theory and practice in electrical engineering—in electrical science generally. Of course, branches of engineering not purely electric are included, but the special subject of this Society is now, and I think must always be, electricity. Electric science hopes much from the observations of telegraphists, and particularly with the great means of observing that they have at their disposal. Science, I hope, will continue to confer benefits on the practical operator. This Society seems essential to make sure that the best that science can do shall be done for the practical operator, and that the work and observations of practical operators shall be brought together, through the channels of the various sub-sections, into one grand stream which this Society will be the means of utilizing.

ELECTRO-MAGNETS.

By COUNT DU MONCEL.

From "The Telegraphic Journal."

In my last note to the Academy of Sciences of Paris, I laid down a very simple formula, by which the diameter to be given to the core of a soft iron electro-magnet may be determined, that shall secure the best possible conditions in relation to the electro-motive force and resistance of a given circuit. This formula, which leads implicitly to the conclusion that, in the case where an electro-magnet is established under all maximum conditions, the diameter is independent of the resistance of the circuit, and proportional to the $\frac{2}{3}$ power of the electromotive force, only with relation to an electromotor, of which the wire is of the same diameter as that of the circuit. But this is not a general case, and it was desirable that the formula should extend to circuits composed of conductors different, whether in nature or in size. This part of the problem is that which I solve to-day.

We have seen that, in order to obtain the value c, that is to say, of the diameter of the iron of the electro-magnet, I took Muller's law, formulated by the equation

$$\frac{I\,t}{I'\,t'} = \frac{\sqrt{c^3}}{\sqrt{c'^3}}$$

c and c' representing the diameters of two electro-magnets, of which one, c', is the standard (*type de comparison*), which we suppose placed under convenient conditions; I and I′ are the current intensities; $t\ t'$ the number of turns of spirals of the two helices.

We have seen further, that in order to obtain the values of t and t' in functions of known quantities, I have had recourse to the formulæ derived from the conditions of maximum of electro-magnets, with relation to their magnetizing bobbin, which give—

$$t = \frac{m\,c^2}{g^2}, R = \frac{2\pi\,c^3 m}{g^2}, I = \frac{E}{R + \frac{\pi\,c^3\,m}{g^2}}$$

m representing the coefficient by which it is necessary to multiply the diameter c, in order to obtain the length of iron of the electro-magnet; g designating the diameter of the wire, covered with its insulating envelope; R, the resistance of the exterior, and E the total electro-motive force.* When the conductor of the exterior circuit is under the same conditions as the wire that constitutes the helix of the electro-magnet, R need not be reduced in function of g to furnish the value of t; but it is no longer the same if, the wire having an indeterminate diam-

*"Comptes Rendus," vol. lxxxi., p. 1405.

eter, R is expressed in units of resistance other than that which serves to measure the length of the wire. It then becomes necessary to reduce R in function of g, for at least the evaluation of t. Now, as this reduction has for its expression $\frac{q\,R\,g^2}{f^2}$ (q representing a length equal to 375,000, when R is expressed in units of telegraph wire of 4 m. m. diameter, and f being the coefficient by which it is necessary to divide g, in order to obtain the wire deprived of its silk covering), we obtain for the value of t—

$$t = \frac{m\,c^2\sqrt{q\,R}}{\sqrt{f^2\,2\,\pi\,c^3\,m}} = \sqrt{v}\,\frac{\sqrt{R}}{f}\,\frac{m\sqrt{q}}{\sqrt{2\pi m}}.$$

The second part of the second member of this equation, being a constant, can be calculated with the known quantities resulting from the data furnished by the standard electro-magnet, and which are $\frac{\sqrt{c^3}}{I'\,t'}$; so that we arrive at the simple expression—

$$c = \frac{E}{f\sqrt{R}}\left(\frac{m\sqrt{c^3\,q}}{2\,I'\,t'\sqrt{2\,\pi\,m}}\right),$$

which may still be freed from the factor f, if we consider it as making for $I'\,t'$ that which it has made for $I\,t$, obtaining the equation—

$$c = c'\,\frac{E}{E'}\,\frac{\sqrt{R'}}{\sqrt{R}}\,\frac{f'}{f}.$$

But the quantity between parentheses of the second member of the preceding equation may be easily calculated; and according to the conditions of the standard electro-magnet I have employed, it is equal to 0.0000288 when f does not figure in the formula, or to 0.00004394 when that quantity is there represented, which is unnecessary, since the ratio $\frac{f'}{f}$ is sensibly equal to I.

There result from this formula several important consequences, which may be rendered thus:—

1. For circuits of equal resistance, the diameters of an electro-magnet should be proportional to the electro-motive forces.

2. For equal electro-motive forces, these diameters should be in inverse ratio to the square root of the resistance of the exterior circuit, comprising the resistance of the battery.

3. The value of these diameters (supposing that the resistance R of the exterior circuit be expressed in metrical units of telegraph wire of 4 m.m. diameter, and that the value of E be calculated upon the hypothesis that the electro-motive force of a Daniell element is represented by 5973) has for its expression—

$$c = \frac{E}{\sqrt{R}}\,0.0000288 \quad . \quad . \text{ metres.}$$

and the figures obtained represent a fraction of a metre.

4. In employing for the value of E the ratio of the given electro-motive force to that of a Daniell element taken as unit, the formula becomes—

$$c = \frac{E}{\sqrt{R}}\,0.172175 \quad . \quad . \text{ metres.}$$

and the value of R be always expressed in metric units of telegraph wire.

5. In reducing the values of E and R to the co-ordinate system of electric measures of the British Association, that is to say, to the *volt* or unit of electro-motive force which represents $\frac{9}{10}$ of the force of a Daniell element, and to the *ohm*, which is equivalent to 100 metres of telegraph wire of 4 m.m. diameter, the formula becomes—

$$c = \frac{E}{\sqrt{R}}\,0.01957 \quad . \quad . \text{ metres.}$$

or, in estimating the diameter in *mils*, the English measure representing thousandths of an inch,

$$c = \frac{E}{\sqrt{R}}\,628.223 \text{ mils.}$$

According to these formulæ, we can calculate that the diameter of an electro-magnet worked by a Bunsen element (medium size) on a circuit having no other resistance than that of the electro-magnet, should be—

$$c = \frac{1.86}{\sqrt{9}}\,0.172175 = 0.0424^{m.}; \text{ or}$$

1 in. 674 mils.

Again an electro-magnet interposed in a circuit of 118,620 metres, and worked by a Daniell battery of 20 elements, should have a diameter represented by—

$$c = \frac{20}{\sqrt{118620}}\,0.172175 = 0.01^{m.}$$

or taking English units,

$$c = \frac{\overset{\text{Volts.}}{21\ 58}}{\sqrt{1186.2}}\,0.015957 = 0.01^{m.} = 393.7 \text{ mils.}$$

The diameter c obtained, the total length of the two bobbins of the electro-magnet become, for the first, 51 centimetres, or 25½ centimetres for each of the branches; and, for the second, 12 centimetres, or 6 centimetres for each bobbin.

The size of the wire can, as I have already said, be deduced from the following equations, when c is determined.*

$$g = \sqrt{f \sqrt{\frac{c^2}{K}}} 0.00002106 \text{ metres},$$

which gives, for the first electro-magnet, $g = 0.04865m.$, comprising the insulating covering, and $0.00336m.$, without this covering. The length of the wire is, with this diameter, $242.8m.$, and this quantity, reduced in telegraph wire (by dividing by 6 and by multiplying by the ratio of the sections), gives 57 metres as the value of R. For the second electro-magnet, these values are $g = 0.0002597$ with the insulating covering, and 0.0001583 without the covering, with a length of wire of $1116.7m.$

The attractive force of these two electro-magnets with distance of the armature of 1 m.m., and taking the force of the standard electro-magnet, which is 25 grammes for a circuit of 1186.20 metres, is, for the first, 23.112 kilograms, and for the second, 26.85 grms.; this at least is the force which results from the laws of Dub and Müller, represented by the formula—

$$\frac{F}{F'} = \frac{I^2 t^2 c^{\frac{3}{2}}}{I'^2 t'^2 c'^{\frac{3}{2}}}.$$

These several formulæ show why the electro-magnets interposed on long circuits should be of small dimensions, wound with fine wire; and why, on the contrary, they should be large when the circuit is short.

* The coefficient of this formula is a little lower than that I have given (vol. lxxvii., p 351, of "Comptes Rendus.") This is owing to my expressing the ratio of the conductivities of iron and copper higher than it is practically, and that the diameter of the iron was below its true value.

DYNAMITE EXPERIMENTS.

From "London Mining Journal."

Some exceedingly interesting experiments with Dynamite, as a blasting agent, were recently conducted at Bardon Hill Granite Quarry, near Leicester. The Bardon Hill Quarry is one of the largest and oldest in the neighborhood, and is noted for the extreme hardness of its stone. The first truck load of stone for road-making sent into London by rail was sent from this noted quarry. The stone which is being got out, according to an analysis made some three years ago, by Kirkcaldy, proves this granite to be the hardest in the country, which the following table will show:—

	Pressure on 1 sq. in. Crushed at lbs.	Pressure on 1 sq. ft. Crushed at tons.
Bardon Hill Quarry	20,742	1334
Mansfield "	19,096	1228
Mount Sorrel "	17,533	1128
Grimsby "	15,062	970

By the above it is clearly shown that of the four quarries Bardon Hill granite is by far the hardest, and it frequently happens that in this quarry 50 lbs. weight of powder is used at a blast, and on one occasion as much as 500 lbs. of powder was used at a charge. The stone got from this quarry is crushed by machinery into different sizes, and is much sought after for road and drive making, from the fact of its being so tough; it is also used for building purposes.

Mr. Thomas Johnson, of the firm of Johnson and Co., Trindle-road, Dudley, attended to conduct the experiments. As there was a good programme to go through, the proceedings commenced early. Messrs. Ellis and Everard desired to see for the first experiment some large loose pieces of granite broken. These were detached from the solid and lying at the bottom of the quarry, some of them weighing as much as 6 or 8 tons each. It is usual in breaking these blocks of stone by blasting-powder to churn a hole in 10 to 12 in. deep, and it often occurs in doing so the workman, in consequence of the excessive hard nature of the granite, loses the points of half-a-dozen steel tools in doing so. There were some seven or eight of these monster blocks of granite to practise upon with dynamite, and a hole was churned in each piece sufficiently deep enough to cover the cartridge, which were some of the smaller ones, 3¼ in. long by 1¼ in. in diameter. A single dynamite cartridge, primed with cap and fuse, was inserted into one of the largest of these blocks, a little clay being

placed over it, so as to tack it to its place; the shot was fired, and when the visitors returned to the spot they were agreeably surprised at the execution done by one single cartridge, the piece of granite being shivered into fragments.

The next experiment was by breaking two of the pieces of granite by firing them together, to show how time may be saved by breaking the two at once. Consequently two of the largest pieces were selected by the party, and charged with one small cartridge each, a little clay being put over them. Both charges were fired, and there was only a quarter of a minute between the two reports, and on the party returning it was found that both pieces were broken to atoms, and tumbled in all directions.

The next experiment was what is usually known in the quarry as a heaving shot—a solid mass of stone lying at the bottom of the quarry that required blowing, or, in other words, heaven up, before other stone can be comfortably worked. In this solid mass a hole was drilled 1⅛ in. in diameter and 20 in. deep; a 1¼ in. cartridge was gently rammed home with a wooden rammer. The hole was then filled up with water, which seemed to surprise the visitors. The charge was fired, and the whole mass lifted up so that it could be conveniently loaded without the use of the sledge. Mr. Everard, one of the firm, said he felt highly pleased with this experiment, as he considered this the most difficult of all the experiments that had been tried.

The next experiment was a breast shot in the solid. A hole was bored in the granite some 12 ft. up the face, 4 ft. deep, and 2½ in. in diameter. As this hole was by mistake put in 2¼ in. diameter instead of 1¼ in., and would not fit the 1¼ in. cartridges, Mr. Johnson loaded the hole with the loose dynamite out of six cartridges; the hole was then rammed up with sand, the charge was fired, and the whole layer of granite dropped; one of the visitors saying he should judge that there were 80 tons brought down by this shot. The next experiment was by throwing a cartridge against the rugged sides of the quarry, to show that dynamite will not explode by concussion; the cartridge simply struck, bursted itself, and dropped like so much loose sand. The next, and last, experiment was throwing cartridges into a blazing fire, which had been made in the quarry, to show that fire will not explode it, the consequence being that the dynamite mouldered away like so much cork burning. Of many experiments with Explosives at this quarry none have proved so satisfactory as those with dynamite.

ON THE CHOICE OF STEAM-ENGINES AND BOILERS.*

From "English Mechanic and World of Science."

It is estimated that 75 per cent. of the whole quantity of coal raised in Britain is absorbed in our various manufacturing industries, and the total quantity increases yearly. By far the greater proportion of this is no doubt consumed in the manufacture of iron, but the quantity of coal devoted to the production of motive power in the iron and other industries is very considerable. In the good old days of cheap coal, cheap labor, and easy competition, economy of manufacture was but little studied. Now, however, in many manufactures the most rigid economy has to be practised, if profits are to be made. And with coal at its present price, manufacturers scarcely need to be reminded that a low-priced wasteful steam-engine means a serious diminution of the yearly profits.

Economical steam power is, however, a compound result made up of many factors, of which safety is of first importance, since it is evident that a single explosion may in a moment cause a loss of life and property infinitely greater in value than the result of many years' economical working. Freedom from break-downs is also highly necessary to economical steam power, as it is easily conceivable that the inconvenience and loss arising from the stoppage of work consequent on a break-down of the engine, would in many cases outweigh any gain arising from economy of fuel merely. The cost of the engine itself, and the cost of its repairs, is another necessary consideration, because it is quite possible to buy economy of fuel at too high a price. If, for instance,

* Extract from a pamphlet entitled "Useful Information on Steam Power," by Henry Northcott.

the interest on the extra cost of the so called economical engine, with its yearly extra cost of repairs, exceeds the value of the fuel saved, the manufacturer is evidently paying more than twenty shillings for a sovereign. That a steam-engine may be safe, durable, and economical of fuel, there need be no manner of doubt; but some little care and discrimination are required in the choice of an engine that shall combine these good qualities.

Careful experiments by Favre, Silbermann, and others, have shown that a pound of good coal will liberate during complete combustion 14,000 or 15,000 units of heat, each unit being equivalent to 772 foot-pounds. The mechanical equivalent of the heat developed by the combustion of a pound of coal is, therefore, say $14{,}500 \times 772 =$ over 11,000,000 foot-pounds. A horse-power is always assumed to be equal to 33,000 foot-pounds per minute, or 1,980,000 foot-pounds per hour. So that the combustion of each pound of coal per hour liberates heat enough to develop $11{,}000{,}000 \div 1{,}980{,}000 =$ say, 5 horse-power; and in a perfect steam-engine the consumption of coal would be about at the rate of one-fifth of a pound per hour for each horse-power developed.

The greatest economy obtained in ordinary continuous working may be taken at from 3 to 4 lbs. of coal per indicated horse-power, with non-condensing engines and from 2 to 2½ lbs. with condensing engines. A consumption as little as 1¼ or 1½ lb. per indicated horse-power has been reported in the case of compound condensing engines, and such results are quite possible. But a consumption of 2 lbs. is as little as can yet be counted on with certainty. The manufacturer, in choosing an engine, would do well to look with some little doubt on promises of a better result than this, and he may feel satisfied if the engine he buys shows itself capable of working with that degree of economy. A consumption of 4 lbs. of coal per indicated horse-power per hour, means a loss of nineteen-twentieths; and of 2 lbs. per indicated horse-power, a loss of nine-tenths of the power theoretically due to the coal. There is, therefore, ample room for improvement, even upon the best of modern steam-engines.

The conditions necessary to economy in the steam-engine are, 1st: The complete combustion of the fuel in the furnace. 2d. The transfer of all the heat generated to the water in the boiler. 3d. The passage of the steam through the engine without loss of heat, except such as is converted into motive power, and the conservation of the heat remaining in the steam on its leaving the cylinder. 4th. The absence of friction in the working of the engine. Let us see how these conditions are fulfilled in a good modern steam-engine.

As to the combustion of the fuel, with the best coal and most careful stoking, a quantity of the coal falls through the fire-bars, either as unburnt coal or as ashes. Another portion goes up the chimney unconsumed in the form of smoke and soot; and a further quantity half consumed in the form of carbonic oxide. The loss from these causes may amount to from 2 to 20 per cent. It all arises from wrongly constructed furnaces and bad stoking, and it may nearly all be avoided.

As to the heat generated,—most coal contains a greater or less quantity of moisture, and the evaporation of this moisture causes the first loss of heat. Radiation from the furnace causes a further loss. But the great causes of loss are the admission into the furnace of a large quantity of useless air and inert gases, and the escape of these with the actual products of combustion, up the chimney, at a very much higher temperature than that at which they entered the furnace. Air is composed of about one-third oxygen and two-thirds nitrogen. The oxygen only is required to effect the combustion of the fuel, and the useless nitrogen merely abstracts heat from the combustibles, and lowers the temperature of the furnace. About 12 lbs. of air contain sufficient oxygen to effect the combustion of 1 lb. of coal, but owing to the difficulty of bringing the carbon into contact with the oxygen, the quantity actually required to pass through the furnace is from 18 lbs. to 24 lbs. of air per pound of coal burnt. The surplus air passes out unburnt, but its presence in the furnace lowers the temperature subsisting there, and abstracts a portion of the heat generated. And whereas the whole of the air enters the furnace at about 60 deg. Fahr., the unconsumed air and the products of combustion leave the flues at from 400 deg. Fahr. to 800 deg. Fahr. The total loss from these causes is from 20 to 50 per cent. In other words, whereas each pound of good coal burnt is theoretically capable of evaporating about 15 lbs. of water in good

practice it evaporates but 9 or 10 lbs., and in ordinary practice but 6 or 8 lbs. of water.

There are difficulties in the way of abstracting all the heat from the furnace gases: firstly, because with natural or chimney draught, the gases require to pass into the chimney at not less than 500 deg. Fahr., in order to maintain the draught; and secondly, because the transmission of heat from the gases to the water, when the difference of their temperatures is small, is so slow, that an enormous extension of the surface in contact with them becomes necessary in order to effect it. But by having energetic combustion and a high temperature in the furnace, the quantity of air actually required may be much reduced; by suitable arrangements for admitting air and feeding the coal into the furnace, the proportions of each may be suitably adjusted to each other; and by a liberal allowance of properly-disposed heating surface, the temperature of the reduced quantity of furnace gases may be reduced to that simply necessary to produce a draught, in a furnace with natural draught, or to about 400 deg. Fahr. or less, in a furnace where the draught is obtained from a steam-jet or fan. Under these conditions an evaporation of from 10 to 12 or more pounds of water per pound of good coal burnt, may be expected.

As to the heat in the steam,—amongst the minor causes of loss are, radiation from the boiler, steampipes, and engine (most of which can be prevented by careful lagging with a good non-conductor of heat); blowing-off, and leakage. A greater loss arises from initial condensation in unjacketed cylinders, nearly prevented by using a properly-constructed steam-jacket. But the great loss arises from the escape of the steam into the atmosphere, with only a portion of its heat utilized. This, of itself, leads to another great loss of from 40 to 60 per cent.

The use of high-pressure steam, high rates of expansion, and of an efficient feed-water heater, is conducive to economy, but no practicable means have yet been devised whereby the whole heat may be saved; and the removal of this source of loss in the working of the steam engine offers one of the most promising subjects for inventive genius.

In a good modern steam-engine the coal used is thus approximately disposed of:—

Lost through bad stoking and incomplete combustion	10.0
Carried off in the chimney gases	30.0
Carried away in the exhaust steam	50.0
Utilized in motive power (indicated)	10.0
	100.0

Engine Friction.—A further loss of useful effect ensues from a portion of the motive power actually developed being absorbed in driving the engine itself, and the useful power of the engine is reduced from this cause by from 5 to 25 per cent. The use of equilibrium valves, ample bearing surfaces, careful lubrication, and cleanliness, go far to lessen the friction, as well as to increase the working life of a steam-engine; but in selecting an engine it is as well to bear in mind this source of loss, as injudicious improvements, introduced for the attainment of increased economy, may defeat this object through the excessive power required to drive them.

For engines with cylinders less than 6 or 8 in. diameter, the simple high pressure non-condensing arrangement should be adhered to, as it makes for small powers the most economical as well as the cheapest engine. The boilers for the smaller powers can be heated by gas instead of by coal, and the cleanliness and convenience of the arrangement quite counterbalance the slight increase of expense. When also the trouble of attending often to the water-level is objected to, a boiler of large capacity should be provided. Non-condensing engines with cylinders above 8 in. diam. should always be provided with expansion valves, steam-jacketed cylinders, and feed-water heaters; and the exhaust steam of non-condensing engines should always be used to urge the draught. Condensers cannot well be used for portable engines or engines requiring removal; but fixed engines, having cylinders larger than about 10 or 12 in., should be fitted with either surface or jet condensers. The jet condenser is less costly and nearly as efficient as the surface condenser, under ordinary circumstances; but when the water from which steam is made contains much impurity, surface condensation is to be preferred. For seagoing purposes engines are now very generally made on the compound system, and some very good results have been obtained from such engines. Their use for land purposes also is becoming very general, and for large powers the compound engine is to be recommended. But it should be borne in mind, that whereas a

compound engine must be both designed and constructed with the greatest skill and care, in order that it may work with greater economy than a good ordinary engine, a bad compound engine may easily be much more wasteful than even a bad ordinary engine.

The unmistakable tendency of modern steam-engineering is towards much higher pressures of steam than those hitherto used. A pressure of over 100 lbs. per inch means the supercession of what may be termed large-capacity boilers. High-pressures are as safe as low-pressures, provided the boilers are suitably designed to withstand them. But the construction of high-pressure boilers should be confided to none but competent engineers; and those who intend putting up new boilers should recollect that the boiler-maker who uses the best quality plates and workmanship is not likely to send in the lowest tender. His boiler may, nevertheless, be the cheapest. For land purposes and moderate pressures the Cornish boiler will continue to be used. For higher pressures a modification of the French or elephant boiler is better, and the multitubular boiler is also to be preferred. The enormously thick plates found necessary in some modern marine boilers lead to most serious inconvenience, and it becomes essential to stipulate that steam shall not be got up in less than several hours. Many attempts have been made to use tubulous boilers for very high pressures, but as yet without any marked success. A good boiler of the kind, however, is a great desideratum.

The actual, or useful, or dynamometrical horse-power, is the net power of the engine, after allowing for friction, etc., and this alone is the power with which users of steam-engines are concerned. In small engines the useful power can be ascertained accurately by the application of a friction brake or dynamometer. The dynamometer, however, cannot be conveniently applied to large engines, but the indicated power, less an allowance for friction, gives the actual power near enough for most practical purposes.

In comparing the prices of different engine-makers, it is very necessary to look at the actual power an engine exerts, and not to the nominal power, or to the size alone of the cylinder. A nominal horse-power means anything from 1 to 8 actual horse-power, and of two engines of the same size and general construction, one may not only develop much more power than the other, but may do so with a less consumption of fuel per actual horse-power.

Coal varies so much in quality that the consumption of a certain weight per horse-power is not in itself sufficient to show the economy with which an engine works. When an engine consumes so little as 2 lbs. of coal per horse-power, we know that the coal used must be of good quality, and that the engine is an economical one. But the consumption of three or four times that weight of coal per horse-power does not necessarily prove the engine to be a bad one, because the coal used may be but one-third or one-fourth as good. Generally, no doubt the best coal is also the cheapest; but when an inferior quality is used, and it is desired to test the efficiency of a steam-engine, an analysis by a competent chemist will show the relative heating value of the fuel, compared with that of standard quality. The best steam-coal is capable of generating sufficient heat to evaporate about fifteen pounds of water from and at 212 deg. Fahr. per pound properly burnt. The same coal after a long sea-voyage or long exposure to weather often loses much of its calorific power, owing to its partial decomposition, pulverization, absorption of moisture, and other causes. Other kinds of coal contain a large percentage of incombustible matter, and knowing its chemical composition will alone enable one to judge of its comparative theoretical efficiency. Anthracite coals give the best results in generating steam, but bituminous coals may be burnt with a high degree of efficiency under suitable arrangements.

Stoking.—After the engineer has done all he can to attain economy, much of the result remains in the hands of the steam-user. A reduction of $\frac{1}{4}$ lb. of coal per indicated horse-power under 2 lbs., can only at present be effected by the greatest skill on the part of the engineer, whilst a careless or unskilful stoker may easily counteract all the engineer's ingenuity. The use of a high-class steam-engine involves the necessity of employing an intelligent, careful attendant. Not that the work is more difficult, at any rate, with good coal, nor is it so laborious, as less coal has to be thrown into the furnace for a given power. The impracticable style of stoking encouraged by the Royal Agricultural Society certainly involves the most

watchful attention and unceasing labor, and if this were good stoking, carelessness would be excusable. Clean fire-bars, an evenly-spread grate, preliminary coking on the dead plate, and the exercise of some little intelligence in the admission of air and regulation of the draught, are the main points to be attended to by the stoker, and these cannot be said to involve an unreasonable amount either of labor or vigilance. A self-feeding grate is conducive to economy, especially when the coal is small or of inferior quality. Its use lessens the stoker's labor considerably, and it is not easy to find a reason for its comparatively limited adoption.

THE CHANNEL TUNNEL.

From "The Architect."

At a meeting of the Institution of Civil Engineers recently, Mr. Joseph Prestwich read a paper on "The Geological Conditions affecting the Construction of a Tunnel between England and France."

Taking the several formations in their order of superposition, Mr. Prestwich considers that a trough of London clay from 300 ft. to 400 ft., or more, in thickness, extends from the coast of Essex to the coast of France, and, judging from the experience gained in the Tower Subway, and the known impermeability and homogeneity of this formation, he thinks there is no difficulty, from a merely geological point of view, in the construction of a tunnel, but for the extreme distance—the nearest suitable points being 80 miles apart. The Lower Tertiary strata, which came next, were too unimportant and too permeable for tunnel work. The Chalk in this area was from 400 ft. to 1,000 ft. thick; the upper beds were soft and permeable, but the lower beds were so argillaceous and compact as to be comparably impermeable. In fact, in the Hainaut coal fields they effectually shut out the water of the water-bearing Tertiary strata from the underlying Coal Measures. Still, even the Lower Chalk is not suited for tunnel work, owing to its liability to fissures, imperfect impermeability, and exposure in the Channel. The Gault is homogeneous and impermeable, but near Folkestone it is only 130 ft. thick, reduced to 40 ft. at Wissant, so that a tunnel would hardly be feasible. The lower Greensands, 260 ft. thick at Sandgate, thinned off to 50 ft. or 60 ft. at Wissant, and are all far too permeable for any tunnel work. Again, the Wealden strata, 1,200 ft. thick, in Kent, were reduced to a few unimportant rubbly beds in the Boulonnais. To the Portland beds the same objections existed as to the Lower Greensands—both were water-bearing strata. The Kimmeridge clay is 360 ft. thick near Boulogne, and no doubt passes under the Channel, but in Kent it is covered by so great a thickness of Wealden strata as to be almost inaccessible; at the same time it contains subordinate water-bearing beds. Mr. Prestwich is, however, of opinion that, in case of the not improbable denudation of the Portland beds, it might be questionable to carry a tunnel in by the Kimmeridge clay on the French coast, and out by the Wealden beds on the English coast. The Oolitic series presented conditions still less favorable, and the lower beds had been found to be water-bearing in a deep artesian well recently sunk near Boulogne. The experimental deep boring now in progress near Battle would throw much light on this part of the question.

The Palæozoic series, which are next met with, consist of hard Silurian slates, Devonian and carboniferous limestones and coal measures having a probable thickness together of from 12,000 to 15,000 ft. These pass under the chalk in the north of France, crop out in the Boulonnais, are again lost under newer formations near to the coast, and do not reappear until in the neighborhood of Frome and Wells. But, although not exposed on the surface, they have been encountered at a depth of 1,032 ft. at Calais, 985 ft. at Ostend, 1,026 ft. at Harwich, and 1,114 ft. in London. They thus seem to form a subterranean table land of old rocks, covered immediately by the chalk and Tertiary strata. It was only as the southern flank of this old ridge that the Jurassic and Wealden series set in, and beneath these the Palæozoic rock rapidly descended to great depths. Near Boulogne these strata are already 1,000 ft. thick; and at Hythe, Mr. Prestwich estimates that their thickness might be that or more. Sup-

posing the strike of the coal measures and the other Palœozoic rocks to be prolonged from their exposed area in the Boulonnais across the Channel, they would pass under the Cretaceous strata somewhere in the neighborhood of Folkstone, at a depth estimated at about 300 ft., and near Dover at about 600 ft., or nearly at the depth at which they had been found under the chalk at Guines, near Calais, where they were 665 ft. deep. These Palœozoic strata were tilted at high angles, and on the original elevated area they were covered by horizontal Cretaceous strata, the basement beds of which had filled up the interstices of the older rocks, as though with a liquid grouting. The overlying mass of gault and lower chalk also formed a barrier to the passage of water so effectual, that the coal measures were worked without difficulty under the very permeable tertiary and upper chalk of the north of France; and in the neighborhood of Mons, notwithstanding a thickness of 500 ft. to 900 ft. of strata charged with water, the lower chalk shut the water out so effectually that the coal measures were worked in perfect safety, and were found to be perfectly dry under 1,200 ft. of these strata combined. No part of the straits exceeded 186 ft. in depth.

Mr. Prestwich therefore considers that it would be perfectly practicable, so far as safety from the influx of the sea water is concerned, to drive a tunnel through the Palœozoic rocks under the channel between Blanc Nez and Dover. The circumstances are not so unfavorable as at Whitehaven, where galleries have actually been wrought through the coal for 2 miles under the sea. But while, in the case of the London clay, the distance seems almost an insurmountable bar, in the Palœozoic strata the depth becomes a formidable difficulty. These are the main conditions which bear on the construction of a submarine tunnel between England and France. Mr. Prestwich said he was satisfied that on geological grounds alone it was in one case perfectly practicable, and in one or two others it was possibly so; but there were other considerations besides those of a geological nature, and whether or not they admitted of so favorable a solution was questionable.

Supposing that, when considered from a geological point of view, the construction of a tunnel seemed practicable—yet there were great and formidable engineering difficulties—but when the vast progress made during the last half century in engineering science was considered, these difficulties would appear to be not insurmountable, especially if the necessity for the tunnel should arise and the cost was not a bar.

HOW TO PREVENT EXPLOSIONS IN COAL MINES.*

By JONATHAN HARRISON.

From "The London Mining Journal."

To insure safety in mines there must not only be a good plan of the workings with adequate ventilating power, but there must also be vigilant administration of all the mining affairs, united with due subordination of authority, constant inspection, and efficient discipline, for danger is always to be looked for and always to be provided against. The first care of an underviewer—whose business it is to descend the mine daily and see that all is right in the ventilation and general management—must be not to allow the gas to accumulate; nor should it be built up, as it is always a source of danger, which wants avoiding in all mines. If gas is found it must be instantly arrested, and removed by ventilation, either by brattice cloth, bricked work, or packed gob roads or headings.

Men should not be allowed to blast with powder in a fiery mine unless they understand ventilation; also, the men who have the care of the stalls should be competent men, as they have the charge of the workings in the absence of the underviewer or deputy; and great care ought to be taken not to allow large caverns to be left, as such places get filled with gas, and a sudden fall of the barometer, with a large fall of roof, taking place both at once drive the gas out, thereby causing a large body of gas to unite with the passing current already loaded with gas, causing the same current to be overcharged, and rendering the same explosive, and the first defective lamp or

* Being one of the essays written in competition for the Hermon Prizes.

naked light coming near causes an explosion.

To prevent explosions in mines which give off great quantities of gas no air-ways ought to be packed less than 6 ft. by 7 ft., so as to allow the area to be 42 ft.; main returns should have 80 ft. area, and all intakes 70 ft. area; and in mines where all the coal is got out waste packings should be wedged down and built up in the benks 10 ft. apart, to allow the roof to settle more steadily and regularly; also to make it more safe the whole of the gob or gobbing should be made up with refuse sent down the mine, if the workings do not make sufficient to fill up all cavities; but this would incur greater expense in getting the coal. I have known deputies to find gas in the stalls, gate ends, and in the benks, and the men have had safety-lamps, and changed their heated lamps for cooler ones, the men thinking they are quite safe under all conditions; but such things ought not to be allowed, as the men ought to know that gas passing at 11 ft. per second will explode a Davy lamp, which would show them there was danger; but supposing it is a Geordie lamp, and one should be brought into a stall, gate, or benk that has been injured by being crushed, an explosion will take place because of its liability to explode in a current of gas passing at 21 ft. per second. Many scientific men have frequently been directed to that subject, resulting in the publication of much valuable information, and many safety-lamps have been offered for approval; but the general results of experiments and investigation seem to be that the only effectual prevention of explosions must be sought in more efficient means of ventilation, by proper supervision and ordinary care to get plenty of fresh air down the mine, which would be the best safety-lamp. The causes which most frequently vitiate the air are the respiration of the workmen, the combustion of the lamps, the explosions of powder, the spontaneous decomposition of certain mineral substances, such as the sulphurets, which change into sulphates; the coal, which heats and burns spontaneously; the corruption of the wood, the striking of the tools against rocks which contain ores of arsenic or mercury; in addition to which is the natural disengagement of deleterious gases, which penetrate the rocks or are accumulated in the crevices and natural cavities, and sometimes in old workings. The gas thus produced or disengaged disposes itself in the drifts or galleries, according to the order of density, as follows:

Carburetted hydrogen, fire-damp, or inflammable gas	0.555 sp. grav.
Azote, or nitrogen gas	0.976
Atmospheric air	1 000
Sulphuretted hydrogen	1.191
Carbonic acid or choke-damp	1.524

The general precautions employed to get rid of those gases as soon as they are found in creating currents sufficiently active to effect their diffusion with the atmospheric air, and to draw the mixture out of the works before it is prejudicial, constitute the art of ventilation. When the workings of the mine are commenced, and if no particular phenomena facilitate the renewal of air, the respiration alone of the men and the combustion of their lamps are not slow to modify it sensibly—in fact, a workman respires on an average 210 gallons of air per hour, from which he absorbs in part oxygen, and substitutes for oxygen in that space of time 6½ gallons of carbonic acid, his lamp operating with the same intensity as his respiration produces as much carbonic acid, and augments besides the proportion of unconnected azote. The carbonic acid, or choke-damp, which is thus the most immediate and most general product of the workings in the mine, is recognized by its weight; it always occupies the lowest parts of the excavations; its intermixture with air manifests itself by the difficulty of combustion in the lamps, whose flame diminishes in brilliancy in proportion as the acid increases, and ends by extinction when the mixture attains to 1-10th. The carbonic acid manifests itself upon the miners by an oppression which overwhelms them; nevertheless, habits and temperament will greatly vary the proportion of the mixture which some men are able to breathe. Azote, or nitrogen gas, is much less to be dreaded than the carbonic acid, because its action upon the mineral economy is less energetic; besides, its productions can only take place by the absorption of oxygen from the air, and it does not naturally exist in the fissures or cavities of the rocks.

The ordinary lamp of the miner is extinguished when the air contains no more than 15 per cent. of oxygen (the atmospheric air is composed of 21 per cent. of oxygen and 79 per cent. of azote); it is also at this proportion of 85 per cent. of azote that asphyxia, or suffocation, is caused.

Azote manifests itself by the red color of the flame of the lamps, which ends by extinction; it renders perspiration difficult, produces a heaviness of the head, and a hissing or singing in the ears, which seems a mode of action different from that of carbonic acid. Light carburetted hydrogen, or inflammable air, is of all the gases the most dangerous, and that which occasions the greatest number of accidents, chiefly from its property of igniting when in contact with lighted flames, and of exploding when it is mixed in certain proportions with atmospheric air. The action of this gas upon the flame of the lamps is the most certain guide in ascertaining its pressure and proportion. The flames dilate, elongate, and take a bluish tint, which can readily be distinguished by placing the hand between the eye and the flame, so that only the top of it can be seen. As soon as the proportion is equal to a 12th part of the ambient air the mixture is explosive, and if a lamp be carried in it will produce a detonation proportionate to the volume of the mixture, therefore the most violent explosions take place when a volume of light carburetted hydrogen gas is mixed with seven or eight volumes of atmospheric air.

Light carburetted hydrogen gas is principally found in mines of coal, escaping from the cells of this mineral with a slight noise, analogous to that produced by water immediately before boiling; it is generally disengaged in the greatest abundance in places which are in the neighborhood of faults, near which the nature of the coal is often found to be altered. There are also in the interior of coal beds cavities where the gas is pent up under considerable pressure, and from which it escapes suddenly whenever the side of the cavity nearest to the workings is weakened by their approach, so as no longer to be able to withstand the internal pressure.

The coal beds most dangerous are those which are the most valuable for their good qualities. The abundance of fire-damp in some mines is such that to obtain a natural light nothing more is necessary than to bore a small hole in a coal seam, insert a tube, and a perpetual flame may be obtained. Such is the bituminous nature of the coal, and though the system of ventilation at some collieries (where the greatest number of explosions take place) may be considered by the officials of the most perfect kind, yet a careful and continual watchfulness and knowledge of dangerous symptoms must be constantly exercised by the officers and men in the mine, to enable them to proceed with any degree of safety in such a situation, where, on the smallest error, or a contingency unforeseen, as a boy asleep or at play, a heated lamp, a broken wire, a sudden eruption of gas, or a change in the wind, or a sudden eruption of the atmosphere, whether from the falling of parts of the roof or otherwise, the bounds of safety can no longer be preserved, but, tremblingly alive to their danger, they are plunged unresisting victims into the abyss. The state of a mine may be ascertained with a degree of nicety by the combined indications of the barometer, thermometer, and the anemometer. When the barometer indicates a fall, the thermometer a rise, and the wind blows from the E.S.E. or S., an ordinary fiery mine will be certain to pass rapidly into a state of great danger, and particularly mines subject to blowers should not be worked when the barometer is below 29 deg.

As regards the practical part of the workings of mines in all fiery districts a shaft should be sunk 11 ft. in diameter, and when practicable two shafts of the same dimensions should be sunk at the same time, and a third shaft so soon as the coal is proved, the third shaft to be 16 ft. in diameter, to be sunk on the basset of the workings for an upcast shaft, which would be required for 300 acres of coal, and four shafts to be sunk for 600 acres, and so on in proportion. Also I am convinced from experience that in fiery mines to the depth of 400 yards, fans from 30 to 40 ft. in diameter should be used for ventilation, two fans at the upcast and one fan at the downcast, so to have one in readiness in cases of emergency, and in mines more than 400 yards in depth fans of greater dimensions in proportion should be used, and where furnaces are used they should be fed with plenty of fresh air. The workings of the mine ought to be laid out in sections. [A large and well-executed plan for laying out a mine accompanies the paper.] Each section to have its own ventilating current, so that if an explosion should take place in one part of the mine it could be prevented from extending to the other parts of the mine by special air-ways ripped and packed through the goaves or old workings in a separate return, ex-

tending to the upcast and exhausting fan, and in fiery seams headings should be driven to the boundary of the workings so as to bleed the gas, and where gas blowers are known to prevail bore-holes, or little shafts, should be sunk down to the lower coal or shale beds, from which gas often proceeds. Sometimes it lies in cavities, with a very great pressure on the measures, causing the gas to give off in gates, airways, and benks, in which case the Geordie lamp should be used with strict discipline, and a barometer should be kept at the bottom of the shaft, also in the centre of the air-way, so that the deputy would be able to examine it as he passes through the works; and where coal lies at a great depth a great quantity of water is to be met with, which incurs an enormous expense in sinking; in such cases iron pipes, 30 in. in diameter, should be taken down the shafts into the old workings to exhaust the gas out.

In getting the coal on the long wall system, it would allow the goaves to be filled up with the roof and holing refuse, which will prevent the gas from accumulating, and where that system can be practically introduced it is essential for the safety of the mine. The long wall system can be worked from 50 to 500 yards in depth under good, bad, wet, or dry roofs, the stalls varying from 30 to 90 yards in length. I have examined scouring which has been done for 10 or 20 years, and I have found the goaves quite firm and safe, and no caverns left for the gas to accumulate in. In the timbering of mines we have special men to set and draw the wood, and I should always enforce the Special Rule—*i. e.*, to have props set, whether the roofs require them or not. I would not advise any air split to be less than 3,000 cubic feet of air per minute. I am quite aware that there are difficulties to contend with in introducing new systems into some districts, both with the men and the nature of the mines.

It is from experience, careful watchfulness, and study to insure the safety of lives in mines, which led me to write this Essay, to carry out your wishes, and satisfy you if possible, in this noble object, in munificently encouraging men to give their ideas to the world, with a view to prevent explosions in coal mines.

In concluding, I consider that a gentleman who has a seat in Parliament should be appointed as a Minister of Mines, with a staff of eminent mining engineers with whom to consult, to be called a Mining Board, and all colliery proprietors should send in their plans of mines before they commence sinking, so as to have the approval of such Minister and the Mining Board. Such plans to consist of the extent of the estate, the size and number of shafts to be sunk, and also a plan of the proposed workings; also such Minister to have power to appoint Inspectors of Mines, and either add to or diminish their number as the Board may think fit. Also such Board to have power to grant certificates to underviewers of the first and second class, according to their qualifications; and such underviewers who are competent to hold certificates should have power to form a local mining board to give certificates to deputies who are qualified; we should then have a staff of well-trained men, and after time has been given for such qualifications no underviewer or deputy should hold situations of responsibility who do not hold certificates; because upon them depends the practical working of the mines, as one or the other is supposed always to be in charge of the mine, therefore they require a special training, also better facilities for the improvement of the men and the education of the boys employed in mining, which would enable them to think as well as to act in their daily occupations.

FLOW OF WATER IN PIPES AND VESSELS.

By H. T. EDDY, C. E.

A recent attack upon the received theory of hydrodynamics suggests a restatement of the mathematical investigation upon which it depends.*

As is well known, any computations of the amount of water which will be discharged from a given set of pipes or communicating chambers can be only approximate; for the resistance of friction, and the resistance which the water experiences by a sudden change of direction on entering or

* See article on "Hydraulics as an Exact Science," by H. Heineman, in Vol. VI., p. 198, of "Van Vostrand's Engineering Magazine."

leaving a pipe or passing an orifice, are to some extent variable quantities. Their variation depends principally upon the size and shape of the pipes and orifices, and upon the velocity and temperature of the water flowing through them. These resistances have been made the subject of much experiment, the results of which may be found in the works of Weisbach and other authors. By the experiments certain coefficients are obtained which are applied to modify the formula expressing the "theoretic flow," which is the flow on the supposition that there is no resistance experienced from friction, etc. It has been customary to introduce a "coefficient of efflux" for each orifice which the water passes, and also a "coefficient of friction" for each pipe traversed, which coefficients are made to depend principally upon the dimensions of the orifices and pipes, varying as they do but slightly with a change of velocity or temperature.

It is our present purpose to investigate and discuss this formula of theoretic flow.

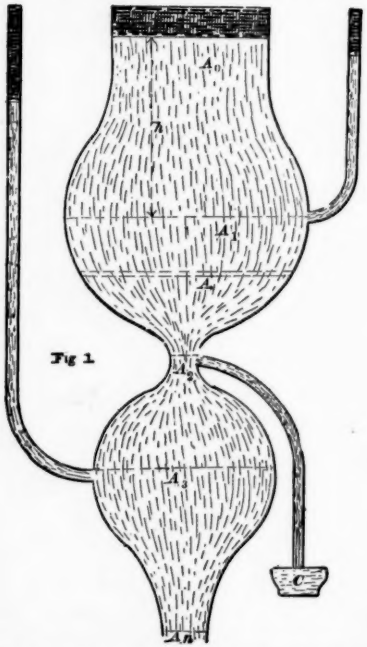


Fig 1

Fig. 1 represents a vessel of varying cross-section which is so short and has so large a diameter that the friction is inconsiderable, and in which the direction of flowing water is changed by easy curves, so that the coefficients of efflux are also small. With such a vessel it is possible to produce the apparently paradoxical results hereafter mentioned.

Let A = the area of any cross-section of the vessel.
A_0 = the area of a particular cross-section of the vessel.
A_1 = the area of another cross-section of the vessel.
A_2 = the area of another cross-section, etc.
And A_n = the area of the orifice of discharge.

Let v = the velocity of flow in the cross-section A.
v_0 = the velocity of flow in the cross-section A_0.
v_1 = the velocity of the flow in the cross-section A_1, etc., etc.
And v_n = the velocity of discharge from A_n.

Let p = the actual pressure per square unit in the cross-section A.
p_0 = the actual pressure per square unit in the cross-section A_0, etc.
And p_n = the actual pressure per square unit in the cross-section A_n.
p_a = the pressure of the atmosphere per square unit.

Let h = the height of A_0 above A.
h_1 = the height of A_0 above A_1, etc., etc.
h_n = the height of A_0 above A_n.

Let g = the acceleration of gravitation.
γ = the weight of a cubit unit of water.
Then $A\,dh$ = volume of an elementary lamina of water.
$\gamma A\,dh$ = weight of an elementary lamina of water.
And $\frac{\gamma}{g} A\,dh$ = mass of an elementary lamina of water.
$A\,dp$ = difference of pressure between the upper and under sides of an elementary lamina of water.

Now if we neglect the effect of friction and efflux, *i. e.*, sudden change of direction, the two causes remaining to control the flow are the weight of the water and the greater pressure at one cross-section than another. That there is less pressure at one cross-section than another is clear in the case of a syphon where the pressure is less in the tube the greater the height above the free surface, or in the case of a Torricellian vacuum, where we find the same thing. It may be easy to see that a similar condition of pressure exists in a tube conveying water when the lower part of the tube is capable of conveying away water more rapidly than can be supplied by the upper part. And further, that this cause is always acting to modify the flow in any vessel, so that we may call $A\,dp$ the *resist-*

ance which the elementary lamina A experiences.

Hence,

A $(\gamma\, d\, h - d\, p)$ = the elementacy force of descent.

Now $\frac{\text{force}}{\text{mass}}$ = acceleration.

$$\therefore \frac{A'\gamma\, d\, h - d\, p)}{\frac{\gamma}{g} A\, d\, h} = \frac{g(d\, h - \frac{1}{\gamma} d\, p)}{d\, h} = \text{acceleration of the water.}$$

But $\frac{d^2 h}{d t^2}$ is the general expression for acceleration.

$$\therefore \frac{d^2 h}{d t^2} = \frac{g\,(d\, h - \frac{1}{\gamma} d\, p)}{d\, h} \quad . \quad . \quad (1.)$$

Again $\frac{\text{space}}{\text{time}}$ = velocity. $\therefore \frac{d\, h}{d\, t} = v$ . . (2.)

Differentiating (2) with respect to t we have

$$\frac{d^2 h}{d t^2} = \frac{d\, v}{d\, t} = \frac{d\, v}{d\, h} \cdot \frac{d\, h}{d\, t} = \frac{d\, v}{d\, h} v \text{ by (2)}$$

$$\therefore \frac{d^2 h}{d\, t^2} = v \frac{d\, v}{d\, h} \quad . \quad . \quad . \quad (3.)$$

Combine (1) and (3), then

$$\frac{g\,(d\, h - \frac{1}{\gamma} d\, p)}{d\, h} = \frac{v\, d\, v}{d\, h}$$

$$\therefore d\, h - \frac{1}{\gamma} d\, p = \frac{1}{g} v\, d\, v \quad . \quad . \quad (4.)$$

The effect of the algebraic work from (1) to (4) was to eliminate t from the equations.

Equation (4) contains three variables, either two of which may be considered to be independent, and the third dependent upon those two. In order to integrate (4), let h and p be the independent variables, and since they are independent, let p be for the moment constant, $\therefore d\, p = 0$, then

$$d\, h = \frac{1}{g} v\, d\, v \quad . \quad . \quad . \quad (5.)$$

And integrating we must add some function (at present unknown) of p.

$$\therefore h = \frac{v^2}{2\, g} + f(p) \quad . \quad . \quad (6.)$$

Now differentiating (6) it must be identical with (4), if (6) is the integral of (4).

$$\therefore d\, h = \frac{1}{g} v\, d\, v + \frac{d}{d\, p} [f(p)].d\, p \quad . \quad (7.)$$

Comparing (4) and (7) we have

$$\frac{1}{\gamma} d\, p = \frac{d}{d\, p} [f(p)].d\, p \quad . \quad . \quad (8.)$$

Divide this by $d\, p$ and clear of fractions, then (8) becomes

$$\frac{1}{\gamma} d\, p = d\,[f(p)] \quad . \quad . \quad (9.)$$

Integrate (9) and

$$\frac{p}{\gamma} + c = f(p) \quad . \quad . \quad (10.)$$

in which c is the constant of integration. On substituting this value of $f(p)$ in (6) we have

$$h - \frac{p}{\gamma} + c = \frac{v^2}{2\, g} \quad . \quad . \quad (11.)$$

Taking this general integral between any two cross-sections as A and A′, *i. e.*, between the limits h and h', p and p', and v and v', we have,

$$h' - h - \frac{p - p'}{\gamma} = \frac{v^2 - v'^2}{2\, g} \quad . \quad . \quad (12.)$$

Which equation expresses all the relations between depth, pressure and velocity, for any two cross-sections, as A and A′.

Since the same amount of water evidently passes every cross-section during a second, $A\, v = A'\, v' = A_n\, v_n$ = amount of discharge per second.

$$\therefore v = \frac{A_n}{A} v_n \text{ and } v' = \frac{A_n}{A'} v_n,$$

and combining these with (12) we have

$$h' - h - \frac{p' - p}{\gamma} = \left[\left(\frac{A_n}{A'}\right)^2 - \left(\frac{A_n}{A}\right)^2\right] \frac{v_n^2}{2\, g} \quad (13.)$$

And from (13) we obtain

$$v_n = \left[\frac{2\, g\left(h' - h - \frac{p' - p}{\gamma}\right)}{\left(\frac{A_n}{A'}\right)^2 - \left(\frac{A_n}{A}\right)^2}\right]^{\frac{1}{2}} \quad . \quad . \quad (14.)$$

Equations (13) and (14) express all the relations which the area and velocity at the orifice of discharge have to the depth, pressure, and areas of any two cross-sections as A and A′. Suppose for instance that A = A′ as in cylindrical tube leading from the bottom of a reservoir, then from (13)

$$h' - h = \frac{p' - p}{\gamma} \quad . \quad . \quad (15.)$$

If the end of the tube from which the water flows is immersed so that the tube is always full, h' and p' may be supposed to refer to the orifice of discharge and then are constant. Equation (15) may then be written

$$h = \frac{p}{\gamma} + c \quad . \quad . \quad (16.)$$

From which it will be seen that p is less,

near the top of the tube, and as the lower end is approached the pressure increases until it becomes that of the atmosphere at the orifice of discharge.

In equations (13) and (14) let A′ coincide with A_n, and A with the surface A_0, and let both be open to the pressure of the atmosphere, then $p = p' = p_a$ and $h = 0$

$$\therefore h_n = \left[1 - \left(\frac{A_n}{A_0}\right)^2\right] \frac{v_n^2}{2g} \quad . \quad (17.)$$

and

$$v_n = \left[\frac{2gh_n}{1 - \left(\frac{A_n}{A_0}\right)^2}\right]^{\frac{1}{2}} \quad . \quad . \quad (18.)$$

Equation (18) is established by Weisbach by a different method, and its validity is disputed by the writer referred to at the commencement of this article, who, among other objections, states that when $A_n = A_0$ then v_n is infinite, which is an absurdity; therefore the formula is untrue. This is the case of a cylindrical pipe, discussed under equation (14), and this or any other of these equations can only apply to vessels or pipes which are kept throughout full of water, for our investigation is only respecting full vessels. The absurdity is in thinking it possible to pour in water at the top of a cylindrical tube in sufficient quantities to keep the tube filled through its entire length.

The writer referred to gives as the correct formula

$$v_n = \left[\frac{gh_n}{1 - \frac{1}{2}\left(\frac{A_n}{A_0}\right)^2}\right]^{\frac{1}{2}} \quad . \quad . \quad (19.)$$

But it is to be noticed that when $2A_0^2 = A_n^2$, *i. e.*, when the tube is larger at the lower end than at the upper in the ratio of $\sqrt{2} : 1$, the same absurdity is found in (19) also.

Again, suppose the orifice of discharge is minute compared with the surface A_0, then $\frac{A_n}{A_0} = 0$ nearly.

$$\therefore v_n = \sqrt{2gh_n} \quad . \quad . \quad (20.)$$

In case the water passes a cross-section of small dimensions as at A_2, let A′ coincide with A_n, and A with A_2, then (13) and (14) become

$$h_n - h_2 - \frac{p_n - p_2}{\gamma} = \left[1 - \left(\frac{A_n}{A_2}\right)^2\right] \frac{v_n^2}{2g} \quad (21.)$$

and

$$v_n = \left[\frac{2g\left(h_n - h_2 - \frac{p_n - p_2}{\gamma}\right)}{1 - \left(\frac{A_n}{A_2}\right)^2}\right]^{\frac{1}{2}} \quad (22.)$$

When $A_2 < A_n$, the second member of (21) is negative, and may become so large numerically as to make $p_2 = p_n$ or even $p_2 < p_n$. Now $p_n = p_a$ the atmospheric pressure. $\therefore p_2$ may be so small that when a hole is made in the side of the vessel at A_2 no water will escape. This may be shown experimentally by noting the height at which a column of water (called a piezometer) can be sustained at A_1, A_2, A_3, etc., by the pressures p_1, p_2, p_3, etc.

Let z_1 = the height of the piezometer at A_1.
z_2 = " " " " A_2. etc.

Then

$$z_1 = \frac{p_1 - p_a}{\gamma} \text{ and } z_2 = \frac{p_2 - p_a}{\gamma}$$

When $p_2 < p_a$, z_2 is negative, and water may be drawn from the cup C as if the piezometer and vessel formed a syphon. This may be seen by coloring the water in the cup.

Let A′ coincide with A_2, and A with A_0,

then since $h = 0$ and $\frac{p_2 - p_a}{\gamma} = z_2$

(13) becomes

$$h_2 - z_2 = \left[\left(\frac{A_n}{A_2}\right)^2 - \left(\frac{A_n}{A_0}\right)^2\right] \frac{V_n}{2g} \quad . \quad . \quad (23.)$$

which shows that the effective head z_2 can never be equal to the hydrostatic head h_2, except when the second member of (23) is nil. This can occur when the velocity $v_n = 0$, or when the areas $A_2 = A_0$. Thus pipes in which water runs are more liable to burst when the water is stopped.

The same laws hold, viz. (13) and (14), when the vessel in Fig. 1 is tipped or bent, provided h and h' be measured vertically to the centres of A and A′, and provided the diameters of A and A′ are small compared with h and h'. Suppose the vessel to be of such a shape that the two cross-sections A and A′ of (13) and (14) are at the same level, then $h' = h$, and we have, if A′ also coincides with A_n

$$\frac{p_n - p}{\gamma} = \left[\left(\frac{A_n}{A}\right)^2 - 1\right] \frac{v_n^2}{2g} \quad . \quad . \quad (24.)$$

and

$$v_n = \left[\frac{2\frac{g}{\gamma}(p_n - p)}{\left(\frac{A_n}{A}\right)^2 - 1}\right]^{\frac{1}{2}} \quad . \quad . \quad (25.)$$

We can apply (24) and (25) to the discharge through a divergent conical tube, as seen in Fig. 2.

It has long been known that so long as the water fills a tube like this to the cross-

section A_n say, that A_n must be regarded as the orifice of discharge and not A_2.

Experiments* by Mr. J. B. Francis, at Lowell, Mass., on the discharge of water through a submerged divergent tube similar to that in Fig. 2, showed such a discharge as to necessitate a value of $p_2 = 0$.

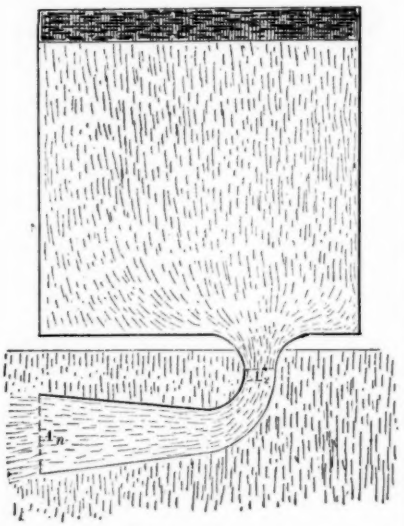


Fig 2

The advantage of a discharge under water is that the submergence insures the filling of the tube by the flow for a much longer distance than can be attained in air.

Application of these same formulas can be made to "Boyden's Diffuser," described in the same work, which is a divergent ring-shaped chamber to receive the water discharged from a turbine wheel, and to remove it at a pressure lower than it would otherwise have been discharged. It acts like a series of divergent tubes around the discharging circumference of the wheel.

Thus the effective head is made to approximate somewhat to the hydrostatic head.

Still further use is made of this principle in turbines to secure a water-tight joint where the water is fed to the wheel. The wheel and "feed" have apertures so proportioned to those which discharge from the wheel, that the internal pressure is nearly that of one atmosphere at the joint; thus there is hardly any tendency to lose water.

Equations (13) and (14) apply also to the case of water urged at A_1 of Fig. 1, by any force, as a piston, causing a pressure p_0 of one, two, or any number of atmospheres, while at A_n the water may be discharged into a receiver at a pressure p_n either less or greater than p_0.

Again, the same equations apply to any incoercible fluid, as mercury, oil, alcohol, etc.

It is useless to urge the insufficiency and absurdity of a theory which covers so wide a range of facts as this, and facts, too, which can each and all be subjected to exact experiment, if it can be shown that the facts corroborate the theory.

I think we are in a position to affirm positively that when such corrections are made for friction and efflux as other experiments show we must make, there is a substantial agreement of theory and experiment.

* See "Lowell Hydraulic Experiments," by J. B. Francis, C. E. Second Edition. Van Nostrand.

REPORTS OF ENGINEERS' SOCIETIES.

ARCHITECTURAL ASSOCIATION (London).—At the last meeting of the members of the Architectural Association, held at its rooms, Conduit Street, Regent Street, W., Mr. Richard Moreland, C. E., read an important paper on "Iron Construction," in which he said that with regard to cast-iron pillars in long columns the transverse section had two duties to perform, viz., to support the load and to resist flexure, so that only one half of the strength of the pillar could be considered available for the resistance to crushing, and the other half for the resistance to flexure. In other words, one-half was in compression and the other half in tension: and this was precisely the condition in which a girder was in; or it might be taken as a question of leverage, the length of one end being the diameter of the pillar, and the other half-length of the column; but in the case where the pillar was large in comparison to its length, then the whole of the material must be taken to resist the compression of a considerable portion of its crushing strength. The working load on pillars should not exceed one-tenth to one-sixth of their breaking, and, under ordinary circumstances, should not exceed 25 diameters. Special care should be taken when the pillar was subject to transverse strains, where heavy goods of unstable form were piled against them, as a considerable strain might be produced from this cause; and also in the event of blows from rolling goods or other causes. Pillars in juxtaposition to brick walls took the whole load when they were strong enough to bear it: but masonry served to stiffen the pillar if secured to it: but if the wall was built in cement, and of considerable thickness in comparison to the iron

pillars, they then possibly might assist each other. In cases where the brickwork was liable to be compressed, and the pillar unequal to its load, then obviously nearly the whole weight must be discharged on the pillar; but care must be taken, as possibly intense compression might take place at the base of the pillar. The basis should be as level as possible. Short columns under crushing force were deformed by pyramid wedges forming at the ends and forcing out wedges at the sides; this was also seen in the crushing of stone and other solid materials. For various forms and sections of pillars, and also of different lengths, the strength of the material would vary considerably under the diverse conditions in which it was placed. For small proportions of length to diameter, cast iron was the strongest material, but its strength diminished, as the proportion of length to diameter increased, faster than wrought-iron; and in comparison of solid square or wrought-iron pillars, with solid round cast-iron pillars beyond twenty-six and a-half diameters, wrought iron was stronger. For ordinary work no cast-iron columns should exceed twenty-seven diameters. The elasticity of cast iron was twice as great as that of wrought iron. The strength of girders to resist resilience was proportional to the weight of the beam, irrespective of the length, so that a beam twice the weight or twice the length would take twice the load to produce the same deflection. Rolled girders were only economical up to a given size and weight.

He then referred at length to the wrought-iron trussel girders placed over the dining-hall at De Keyser's "Royal Hotel," and said that, in designing the outline of the iron work of these beams, Mr. Greening, the architect of the building, had several objects in view. The thickness of the floors through which the structure was fixed should not be thicker than the other floors, and that, generally, the girders comprising the truss should be limited in depth, so as not to interfere with the heights of the various rooms: the central space, too, should be quite open. The two side spaces being occupied with chimney breasts and flues, economy of space and material, together with great rigidity, were thereby attained. The construction of the six trusses must be briefly described. Two wrought-iron girders were taken for upper and lower members of the truss, and distanced apart by two vertical girders, and so dividing the space into nearly three equal parts. From the junction of the vertical girder with the upper girder to the ends of the lower girder another wrought iron girder was placed at an angle, and securely bolted and secured at the ends. Each of the long girders, independent of the truss construction, would be able only to support its own area of floor, say 1 to 1½ cwt. per foot; but by the employment of these girders as upper and lower members to the construction, these, by the addition of about the weight of one girder and a half, were made to support a load of ten times that which they would carry by themselves. The three lower girders were placed immediately above the dining hall; the lower girder was only 10 in. deep, 12 in. wide; the upper girder was 16 in. deep, 12 in. wide; the length was 30 ft. 3 in.: and the span between walls 35 ft. 6 in.; and the whole height was 9 ft. 3 in. The distance between the vertical rods was 15 ft. 6 in., so that a space was given of 7 ft. 1 in. high by 15 ft. 6 in. wide. In the centre of the girders the diagonal trusses were of the same section as the lower girder. The sectional area of the lower girder and trusses was 46 sq. in., and deducing 8 in. for rivets, gave a net sectional area of 38 sq. in. The upper girder had a gross section of 48 in., which was all available for compression. The foot of each diagonal was bolted to the lower girder and an angle casting was also secured to it and the lower girder; and similar castings were also fixed at the junction of the vertical girders with the upper end of the diagonals. Each separate piece of the truss was riveted together and laid in position, the corner castings fitted, and the whole of the holes drilled, after being carefully put together; and the various portions were then fixed in their respective positions and securely bolted together. The summary of the load on the girder was 200½ tons.

IRON AND STEEL NOTES.

CHEMISTRY OF THE BESSEMER PROCESS.—The conclusions reached by Kessler in regard to the theory of the Bessemer process may possess some interest to our metallurgical readers, since they differ somewhat from the views generally advocated.

The observer in question finds that in the Bessemer process of steel-making the entire amount of carbon present at first is relatively increased, owing to the more energetic oxidation of certain other substances in the iron in the earlier portions of the "blow," and that the carbon first begins to oxidize after the major portion of the silicon has disappeared.

Concerning phosphorus—the most obstinate impurity—Kessler declares that its amount is decreased during the middle portion of the process, but that its proportion is relatively increased both at the commencement of the "blow," owing to the more energetic oxidation of the other impurities, and towards the end of the operation, when it is, to some extent at least, taken up again from the slag. Sulphur decreases rapidly at first, but increases again in the middle stage, up to the addition of the spiegeleisen, for the reason that a portion of it, which in the first stage went into the slag, is afterwards taken up again by the iron. When the spiegeleisen is added and the "blow" recommenced, the sulphur again diminishes, and the suggestion is made that if it were possible to remove the first slag, which, contains much of the sulphurous impurities, it would be possible to use brands of iron which are known to contain sulphur for making Bessemer steel.—*Journal of the Franklin Institute, Philadelphia.*

IRON TRADE IN READING.—In this country there is capacity for making 3,000,000 tons of pig iron per annum, including the run of the new furnaces, completed this year; and since we can no longer draw to any extent upon the British market, which is taxed to supply the Continental and other demands, that amount should not exceed the annual requirements. With the country's present mileage, 700,000 tons of new and re-rolled rails will be required for renewals during 1874, and this is within less than 100,000 tons of the present maximum capacity of the rail mills. To

this must be added the amount needed for the extensions, sidings, etc., for new roads which are far advanced, and for additional tracks which some of the trunk lines already find necessary for the separate accommodation of freight and passenger traffic. The market is now almost wholly relieved of foreign rails. The importations have practically ceased, and as prices on the other side are likely to be maintained, they cannot be sent here profitably in competition with the American product. This leaves the field pretty much to our own iron masters, and the probabilities are that the demand this year will keep them well employed, even though we should build less than a quarter of the mileage completed in 1872. In that year about one-third of our total production of iron went into railroads, and, with foreign supplies practically cut off, there seems to be no good reason for supposing that we shall not want as great proportion in 1874.

MISSOURI IRON PRODUCT.—The statistics for 1873 show a marvellous and most gratifying progress in the manufacture of iron in this State. In 1870 the United States Census reported in Missouri 15 blast furnaces, employing $1,914,000 and yielding $586,293. In 1873 we have 12 establishments, with 18 furnaces, $5,783,000 capital, employing 2,421 hands, paying $1,089,300 wages, and yielding 100,000 tons of pig, valued at $4,500,000, and 120,000 tons of rails, valued at $1,008,000,—a total of $5,508,000. Thus in three years the capital employed in iron and rail making has trebled, the number of hands has more than doubled, and the product has been increased fourfold. Our State has gone into iron making in earnest, and as iron can be produced cheaper here than in either Pennsylvania or Ohio, we may confidently expect that the next Census will show Missouri one of the leading iron States.—*St. Louis Republican.*

THE HENDERSON PROCESS FOR THE MANUFACTURE OF WROUGHT IRON.—Messrs. Cooper, Hewitt & Co. have completed arrangements for the manufacture, at their mill in Trenton, N. J., of wrought iron by the Henderson process, and as soon as the necessary supply of fluor-spar shall have arrived at the mill, they will be prepared to fill orders for any quantity of this iron which may be required by the trade. This process, which has merited and received the commendation of the most scientific and successful iron masters of Europe, and which has now been adopted by one of the best known firms in the iron trade of this country, opens a new and inviting field of enterprise to the American iron manufacturer. By it ordinary qualities of pig iron may be made into wrought iron of superior purity, softness and ductility, at a cost but little exceeding that of ordinary puddling, and very much cheaper than the price of corresponding grades of Swedish and British iron in this market.

There is no wrought iron now made in this country which is a substitute for the high class Swedish iron for the manufacture of tools and cast steel of the best qualities, and large quantities are annually imported for these uses. The reason that the Swedish irons are better than other kinds is, that they are nearly pure, and are consequently very soft and ductile. The same results are had when any kind of pig iron is treated so as to render the wrought iron pure. This, however, is not possible by the puddling process; but other means have been discovered to effect this object. We have noticed at different times results obtained by the use of the Henderson process, and we have recently had ample confirmation of what we have before written about it. This process yields a pure, soft and ductile wrought iron, even when using ordinary or inferior pig iron. It has the high tensile strength of the superior qualities of Yorkshire bar combined with the softness and ductility of the Swedish, and is, therefore, of superior value for all purposes to which wrought iron is applied. Its purity has been shown by chemical analysis, and its strength, softness and ductility by mechanical tests in testing machines. Softness is ascertained by the amount the specimen contracts at the point of rupture, and ductility by the amount that it stretches before breaking.

NOTES ON THE DEFINITION OF STEEL.—The author remarks that it is time to fix the terms of a good definition of steel. As far back as 1869 he proposed to reserve this name for all *malleable siderurgical products obtained in a state of fusion*, reserving the term "iron" for every malleable product which has not undergone fusion. From this definition, it follows that the ancient steels, with the exception of cast steel, can be regarded merely as irons more or less carburetted and steely. Cast steel, as well as the new metals bearing the names of Bessemer, Siemens, Martin, etc., are the only true steels having the characteristic of being obtained in a liquid state, and run into homogeneous and compact blocks or ingots. Homogeneity and compactness, natural consequences of the liquid state, are the two characteristics of these metals, and belong to steel only. It is well known that masses of crude iron result merely from the juxtaposition of grains of iron at a comparatively low temperature, amidst a slag more or less liquid. By the processes of shingling and rolling, the greater part of the impurities are squeezed out of this metallic sponge, and the particles of iron are brought sufficiently near to each other to be more or less perfectly welded together. Thus a rough, crude outline of iron is obtained—the primitive form in which iron is met with in commerce, and which is very different from that of crude steel. The latter, obtained at an extremely high temperature, is composed of small drops of iron, more or less completely carburetted, entirely exempt from slag, and forming, when cool, a homogeneous and compact block or ingot. It is the high temperature attained which impresses a peculiar character on the new metals. In fact no other means is so effectual for expelling slag and rendering a metallic mass homogeneous. In practice, the distinctions just pointed out cause the difference of the uses to which iron and steel are put. If the manufacturer requires a metal capable of resisting wear and tear, iron will not be selected. Mere juxtaposition of particles implies want of compactness, and probability of exfoliation and roughness of surface. This is the case with rails, especially at stations, inclines, and crossings, and with all articles exposed to great friction. If, again, a metal is required capable of bearing shocks and prolonged vibration, steel, if the respective tenacity is equal, is still superior

to iron. The want of compactness of the latter involves the beginnings of fissures, which go on increasing till the article is fractured. There are multitudes of purposes for which the homogeneity of steel renders it preferable to iron, in spite of the difference of price. It must not, however, be supposed that steel is destined to supplant iron, especially as the new methods of mechanical puddling will place the latter in an improved position, bringing it a step nearer towards the homogeneity and compactness which are characteristic of cast steel.

At present, siderurgical industry yields two series of products, identical in chemical composition, but differing in the manner in which they are obtained. The first is the scale of irons, commencing with common iron in its different states, passing then to granular iron of different qualities. Next steely iron or puddled steel often so rich in carbon as to admit of being tempered. Sometimes even it is scarcely malleable, like Styrian steel. This is a species of refined cast metal, obtained in furnaces fed with wood, and so far freed from carbon that a single balling in the furnace renders it capable of being shingled—though with difficulty, and then drawn into steel wire of the first quality. At the top of this scale we must also place the cementation irons or steels, which are only irons highly carburetted by the immediate contact of carbon.

The second series forms the scale of steels. It is parallel to the foregoing, and each of its members is analogous to a member of the iron scale. It begins with extra soft steel, which welds like iron, and does not take a temper. Next follows soft steel, corresponding to granular iron and semi-soft steel, representing puddled steel. Lastly comes a hard steel corresponding to the cementation irons or steels, and to Styrian steel. This final number of the scale welds badly and tempers readily. The following table shows the percentage of carbon for both series:

Percentage of Carbon.—0 0.15, 0.15 0.45, 0.45–0.55, 0.55–15.

Series of Irons.—Common irons, granular irons, steely irons or puddled steel, cementation iron or steels, Styrian steels.

Series of Steels.—Extra soft steel, soft steel, semi-soft steel, hard steel.—*Iron.*

NOVELTY IN FORGES.—One of the greatest difficulties that a smith has to contend with in the working or welding of large forgings is the danger of burning part of the iron in endeavoring to obtain a good working or welding heat throughout a considerable mass. This burning, we need scarcely say, has the most deteriorating effect upon the tenacity and elasticity of the iron; and there is little room for doubt that this frequent burning of forgings is the cause of many deplorable accidents to apparently sound cranks, axles, etc.

This great danger in working is caused principally by our present arrangement of ordinary forge hearths. The air-blast is generally introduced by a single tuyere-pipe only, so that the side of the forging presented to the blast will burn long before the other side is cherry red, if the forging be large. The constant attention of the smith is thus required, and considerable labor, also, for the continual turning and moving of the iron to present all sides as often as possible to the blast.

We have just noticed a very simple and neat forge by Messrs. Seel and Shaw, in which the pipe from the air chamber is divided underneath the hearth, and *two* tuyere-pipes are led therefrom into opposite sides of the hearth. This will afford a much more regular heating throughout the mass of a large forging, and the arrangement has given excellent results in practice. The tuyeres are well protected by a water-jacket, which circulates from a cistern placed at the back of the forge.—*Iron.*

RAILWAY NOTES.

THE NARROW GAUGE IN THE UNITED STATES.—We have received from W. W. Nevin, Esq., of Philadelphia, who is connected with the management of the Mexico National Railway Company (the Palmer project), a statement of the progress, and an estimate of the prospects of narrow-gauge construction in the United States. The paper being too extended for reproduction in these colums, we take the liberty of presenting a *résumé* of its chief subject-matter. Col. Nevin characterizes the narrow gauge as a "railway reform movement," which may now claim as accomplished facts: 1. A saving in the first cost of construction about 33 per cent. 2. A saving in operation which shall make the net earnings average 50 per cent. of the gross instead of 33, which has so far been a liberal average for good completed roads. 3. The ability to reach sections where it is physically impossible for roads of the wide gauge to be built at all. With the questions of relative dead and live weight and maximum carrying capacity, next considered, our readers are familiar.

The statistics of construction are especially valuable. The total length of projected narrow-gauge roads in America is given as 4,680½ miles (3,889½ in the United States, and 791 in the Canadas), and of this there are completed 1,364½ miles; 928½ in the United States, and 436 in Canada, as follows:

In the United States.

Name.	Miles built.	Total length.
Denver & Rio Grande	156	870
Cairo & St. Louis	92	150
Utah Northern	70	160
Kansas Central	65	560
Arkansas Central	64	150
Colorado Central (N. G. Division)	42	247
North & South of Georgia	35	130
Montrose	27	27
Ripley	26	36
At Johnston (Private)	25	25
Cherokee, Alabama	23	45
Iowa, Eastern	20	183
Milwaukee & Des Moines	20	300
American Fork, (Utah)	18	22
Pioche, (Nevada)	18	18
Central Valley	12	12
East Broadtop	12	30
Mineral Range, Michigan	12¼	100
Wasatch & Jordan Valley	12	16
Pittsburgh & Castle Shannon	8	8
Bell's Gap	8¼	40
Peekskill Valley	7	7
Summit County, Utah	8¼	30
Tuskegee	5¼	30

Louisville, Harrod's Creek, & Westport	5	28
Painesville & Youngstown	12	65
Baltimore, Swan Lake, & Towsontown	6½	6½
Peachbottom	5	60
Bingham Cannon & Salt Lake	20	20
Ceredo Mineral, W. Va	12	20
Cheraw & Salisbury	11	80
Lawrence & Evergreen	5	5
Echo & Coalville, Utah	9	9
Natchez, Jackson & Columbus	6	260
Galena & Southern Wisconsin	30	150
	928½	3,889½

The following were to have completed additional mileage by Jan, 1874.

Cairo & St. Louis	52	
Des Moines & Minnesota	17	
Parker's Landing and Kansas City	10	
	1,007½	

In the Canadas.

Name.	Miles built.	Total length.
Toronto, Gray, & Bruce	199	200
Toronto & Nipissing	87	218
New Brunswick	70	170
Prince Edward's Island	90	203
	433	791

The following list is given of

Roads actually under Construction:

Name.	Under construction.	Total length.
Florida, Memphis, & Columbia	120	260
Lexington, Lake & Gulf	170	170
Wyandotte, Kansas City & N. Western	50	250
Cairo & Tennessee River (under construction in Duck River Valley, Ala.)	75	100
South Branch (W. Va)	26	51
Cheraw & Salisbury	15	80
Nashville & Vicksburg	26	470
Bainbridge, Cuthbert & Columbus	20	140
California Central	150	465
Des Moines & Sioux City	20	180
Salt Lake, Sevier Valley & Pioche	25	300
Alameda, Oakland & Piedmont	60	60
St. Louis & Manchester	8½	30
Juan, San Pete & Sevier	10	75
Washington, St Louis & Cincinnati	65	950
Greenville & Paint Rock	5	22
Stockton & Ione (California)	36	36
St. Louis & Western	100	315
Denver & Rio Grande	50 miles graded.	
Utah Northern	90 "	"
Arkansas Central	86 "	"
North & South of Georgia	60 "	"
Summit County (Utah)	3½ "	"
Peachbottom	45 "	"
Ceredo Mindral (W. Virginia)	6 "	"
Natchez, Jackson & Columbus	14 "	"

The following

Projected Roads

are organized and more or less under way:

North Pacific Coast	250
Big Sandy Valley	137
People's Narrow Gauge of Iowa	170
Minneapolis, Rochester & La Crescent	140
St. Louis & St. Charles	14
Holly Springs, Brownsville & Ohio (being graded)	
Long Island Narrow Gauge	
Toledo & Maumee	
Northern & Southern Narrow Gauge, N. C.	
St. Louis & Florissant	16
The South Park Railway, Col	260
Tennessee Central	
Memphis & Raleigh	

ENGLISH AND AMERICAN RAILWAYS.—The London "Railway News" has some interesting comparisons of English and American railway returns, and in the matter of rolling stock and train earnings is surprised to find the American roads more economically run than the English. Taking four roads in each country, aggregating about 4,000 miles, it is found that the American road has only .33 of a locomotive and 6.72 freight cars per mile, while the English has .93 of a locomotive and 28.83 cars. The New York Central, with a heavier traffic than the London and North Western, has half the locomotives per mile. The English refuse to believe that the superior size and strength of American locomotives account fully for this difference. The earnings, for instance, of an American locomotive are 70 per cent. more than those of an English, and the entire rolling stock, which in England barely pays for itself in a year, in this country pays for itself and 65 per cent. more. The "News" also discovers that, while passenger fares are 30 per cent. lower than in England, the earnings per train here are 4 per cent. more, and on freight trains 15 per cent. more, than on the English roads.

ENGINEERING STRUCTURES.

ENGINEERING CONSTRUCTION ON THE CONTINENT.—In the way of projects, the Geographical Society of France has received a communication which is startling in its novelty; it appears that there exists from the gulf of Galeès to the meridian of latitude in which the town of Biskra lies, a series of vast depressions called *chotts*, which would be lakes, only there is seldom any water in them. They extend over a length of 180 to 190 miles, with width varying from 12 to 36 miles in width, and the edge of one of them, at least, is more than 80 ft. below the level of the sea. It is believed that at some remote period the whole of these depressions were filled with salt water, and as the first is only separated from the gulf of Galeès by dunes of small extent, it is proposed to cut a canal, and let the waters of the Mediterranean into this vast series of hollows, provided that a survey of the whole of the *chotts* should prove that they are really in connection with each other. The advantages set forth are the creation of sea-ports 50 miles south of Bliskra, the surveillance of the nomad tribes of the south which at present defy the power of France, the consequent domination of the lands to the south of Constantine, and the eventual drawing of the commerce now carried on with Central Africa, by the Touareqs, by way of Tunis, Morocco, and Tripoli. Captain Roudaire concludes by asking the authorities to appoint four surveyors—two to start in one direction, and two in the other, and says that the actual state of the depressions may be ascertained thus in about 100 days.

M. Richard's plan for forming a ship canal to Paris is now more fully before us. The projector

calculates that the canal being once filled sufficient water must be provided for the transport of 1,250,000 tons of imports and 750,000 tons of exports, or on an average 3,000 tons each way per diem. This quantity of water he sets down at 60,000 tons per diem, to which must be added loss by evaporation, by the locks, and by infiltration, making a grand total of 135,000 tons per diem, for that part of the canal lying between Dieppe and the river Oise, to which M. Richard adds 25 per cent. future increase of traffic. For the upper portion of the canal—that between the Oise and Paris, M. Richard calculates on a business of 12,000 tons per day in both directions, and a consequent demand for 185,000 tons of water. He says that the lower part of the canal can be fed from the rivers Eaune, Bethune, and Arques, and the upper arm from the Seine. The total length between Dieppe and Paris is reduced by certain modifications in the original plan to 94 miles, and the cost is estimated at £51,200 per mile. The cost of establishing the port of Paris is given at nearly a million sterling, and the total cost of the whole work at £6,000,000. The port is to cover an area of 675 acres, or more than that of the London docks.

A curious experiment is being tried on the railway bridge across the Seine at the Pont du Jour, with the view of diminishing the great weight of ballast on railway bridges and viaducts: stout canvas is nailed down on light wooden cross-pieces and covered with bitumen, the surface of which is closely covered with small stones, such as are found in garden mould, so as to prevent accident from sparks.

THE BALTIMORE BRIDGE COMPANY.—An incorrect statement in our January issue regarding the work done by this Company is corrected by the following, viz.:

They have built since commencing business in 1866,

Of Wrought Iron Viaduct	20,565	lineal ft.
" Fink Truss	12,934	" "
" Triangular Truss	10,127	" "
" Quadrangular "	9,129	" "
" Girders	2,256	
Total (single track)	55,011	ft.

ORDNANCE AND NAVAL.

CLYDE SHIPBUILDING.—Recent issues of "Iron" give some interesting facts relative to the condition of the shipbuilding industry at its great European centre. A period of slackness has occurred there, lasting for several months; but in September a revival set in, a large number of fresh contracts having been made with various shipbuilding firms for vessels of large size. Curiously enough, a reaction in favor of sailing vessels has taken place, resulting from the high price of coal, and a large proportion of the new iron ships are to be propelled by the air alone. Messrs. M'Millan & Son, Dumbarton, have in hand two iron sailing vessels of 2,200 tons each, for a Liverpool house engaged in the East India trade. When they are launched these will be the largest iron sailing ships afloat. In the early part of November there were 91 vessels on the stocks in the Clyde shipyards, and the builders had every reason to anticipate an increase in their orders instead of the predicted decrease.

The number of vessels launched from Clyde shipyards in September was considerably below the average of the past 9 months, but the tonnage was largely in excess of that launched in any corresponding month. There was an increase of 1,600 tons over the tonnage launched in the same month last year, and fully 4,000 tons over the average of several years, while in the past 9 months there was an increase of 24,000 over 1872, and 41,000 tons over the average of the four preceding years, as shown by the following table:

	Month.		Nine Months.	
	Vessels.	Tons.	Vessels.	Tons.
1873	12	18,600	119	184,500
1872	11	17,000	143	160,500
1871	11	11,800	131	133,300
1870	15	16,000	148	137,000
1869	14	12,500	158	142,000

There were launched from the Clyde shipbuilding yards during October, 14 vessels, the aggregate tonnage of which amounted to 20,170, which is fully 2,000 tons less than was launched in the same month last year; however, the tonnage is fully 3,500 tons more than the average launched in the 4 years 1869—1872 in the same month. The following tabulated statement indicates at a glance the position of the trade, so far as launches are concerned, for a period of five years from the present time:

	Month.		Ten Months.	
	Vessels.	Tons.	Vessels.	Tons.
1873	14	20,150	133	204,500
1872	17	22,250	1 0	182,800
1871	13	17,600	144	150,000
1870	8	7,200	156	144,000
1869	22	19,000	189	160,100

—*Nautical Gazette.*

SAFETY AT SEA.—A NEW SUGGESTION.—A correspondent, A. W. C., who appears to have given some attention to the subject, thinks we are greatly behind-hand in our methods of ocean navigation, and suggests an improvement. In reference to such a loss as that of the Ville du Havre, he asks if it be not time to discard the useless contrivances which are proposed as life-saving, and render the steamers themselves a kind of life-saving mechanism. "The truth is," he says, "the steamer herself should be a life-saving contrivance, built in such a way, or of such material, that she could not sink, even if cut in two, or filled with water to her upper deck. In other words, has not the time arrived when there should be for the exclusive conveyance of passengers and mails a style of vessel that would cross the ocean in a week or less, with absolute security against foundering and fire?

"The ocean steamer of to-day is simply a huge freight-boat. She is somewhat larger, and perhaps a trifle swifter, but certainly not any safer, than when she first crossed the Atlantic, some thirty years ago. And for the chance passenger of those days she did well enough. But look for a moment at the present enormous volume of ocean travel. Doubtless, more have crossed during the last ten years than crossed in all the previous cen-

turies since the time of Columbus. And yet in no department of human industry has so little real progress been made in the last quarter-century as in this.

"It would certainly seem absurd if our railroads had no passenger cars, and we had to travel about the country strapped on to the roof of a freight car. Ocean travel is quite as absurd and even more dangerous, for our tier of state-rooms is strapped on to the top of a heavy iron box, loaded with heavy freight, which, in the event of a sudden blow, goes to the bottom as if it were made of glass. And with all human foresight and caution, such collisions with other vessels or with ice will sometimes occur.

"As to the material, the model and the dimensions of the coming ocean steamer, these are problems which marine engineers must work out. What most naturally suggests itself is a vessel of about the same length as now in use, but broader and shallower, with lines adapted, not to carrying capacity, but to speed; the chief novelty, however, being that the entire hull, excepting the space required for engines and coal, would be filled up with very small air-and-water-tight compartments or cells. Perhaps as much as three-fourths of the entire interior would be devoted to this cellular arrangement, so that the ship would be, in effect, a gigantic life-preserver. All the passenger accommodations, as well as the sailors' quarters, etc., would be upon the main deck.

"The cellular construction of the vessel would add greatly to her strength, while her lightness would admit, at least in ordinary weather, of great speed, and her model would greatly diminish the rolling so provocative of sea-sickness.

"The chief question, of course, is the expense. If it won't pay, it won't be done. It must be remembered that, while the first cost and the running expenses per day would not exceed those of the present style of steamer, the passenger steamer could make twice as many trips in the year, for she would not only be actually faster, but would save much time between voyages which is now spent in discharging and receiving cargo. For the same reason, there being no cargo, she could, after landing her passengers at Plymouth or Brest, start again in a day or two on her return trip. Her passenger accommodations would no doubt be greater than at present, and the mails would add much to the receipts. Besides this, people would pay more for a short voyage to Europe than for a long one, and the feeling of security is worth more than a trifling difference in money.

"It is not contended that such a vessel could not be wrecked. She might be disabled by collision or stranding, but it is hardly possible that she could be sunk by any form of accident that we are familiar with.

"It is to be hoped that before the end of the present decade we shall see the present cumbrous steamers given up entirely to the freight business, for which they are so well adapted, while we ourselves shall glide rapidly across the ocean in vessels which, in the event of accident, we can at least depend upon remaining afloat."

We give the suggestions of our correspondendent for what they are worth, remarking simply that they have at least the merit of originality and interest.—*Evening Post.*

BOOK NOTICES.

A PRACTICAL TREATISE ON THE SLIDE VALVE BY ECCENTRICS. By Prof. C. W. MACCORD. New York: D. Van Nostrand

The author—Prof. C. W. Mac Cord, of the Stevens Institute of Technology—has evidently endeavored, and with marked success, to supply a want felt, probably, by every student of mechanics, by every young draughtsman, and by every ambitious young workman. A book which, concisely yet clearly, gives a knowledge of the principles involved in this form of valve-movement, and instructs its readers in the methods of "laying out" the valve and its motion on the drawing-board, has long been needed.

Algebraic analysis was applied at a very early date, to the expression—mathematically—of the law governing valves moved by eccentrics; but it is not algebraic expressions that a draughtsman desires. He is compelled to translate these formulæ into geometrical constructions, and he does his work by the use of a purely geometrical language. For this purpose, therefore, a geometrical treatment is far more satisfactory than the algebraic, even when, as is not always the case, he finds no difficulty in comprehending the less familiar language, or in making an accurate translation from it into his own. The author of this treatise refers to this fact in the text, and has fully recognized it in the method he has adopted. Himself an accomplished draughtsman, he confines himself in his work to the methods of the craft, and, by the use of neatly made diagrams, has exhibited the processes of geometrical construction applicable to the problem to be solved, representing the several parts in their proper relative proportions and positions. Restricting himself to this task, he has produced a work which is as useful to the student as it is creditable to the writer. The attention is not distracted by the consideration of the relative proportion of the size of the valve to that of the engine, or to the limits of its applicability as an expansion valve. These points are beyond the intended scope of the work.

The movement considered is simply that derived from a single eccentric with direct connections, and no allusion is made either to the link motion or to the various forms of regulating or reversing gear. The one aim is everywhere kept in view—to teach, as completely as possible, the principles of the slide-valve motion governed by a single eccentric: this result is fully attained.

The author states that needless mystery is usually thrown around this subject through the assumption that the three-ported valve is essentially a single detail, and by the introduction at the outset of the consideration of the irregularities produced by the action of the connecting rod and the eccentric rod, so that the beginner is bewildered, if not disheartened, before he has fairly entered upon his task.

Showing that this valve, in reality performing four distinct functions, may be regarded as a combination of four distinct organs, which again may be considered separately, he endeavors to smooth the path of the learner, by at once dividing it into its component parts, and taking them up singly in their order.

In the first chapter, a graphic investigation of

the general character of the motion derived from an eccentric is given, entirely divested of the complications produced by the eccentric rod, and the different ways in which a valve may be made to open and close a port are thus clearly shown, as well as the limits of its action and the peculiarities to be noted in each case.

The systems employed in practical every-day work are next considered, their treatment being rendered equally simple and satisfactory by the conceptions already obtained. Consistently adhering to the synthetic method, both in treatment and in the arrangement of the work, the author first defines his valve as a contrivance governing one port for a single purpose—that of regulating the admission of steam at one end of the cylinder. The operation of the valve thus limited in its functions is now explained in connection with an engine working without expansion; the modification required to produce expansion by "cutting off" the steam at a specified point is next taken up, and "lead" is subsequently considered.

The author criticises the frequently used expression, "in order to make the valve cut off, we add lap," and shows that the lap is the effect of a primary cause, which cause is the change in the angular position of the eccentric; and indicates that it is most correct to regard throughout, the eccentric as the controlling device. A careful study of this chapter should be sufficient to make clear to the most beclouded mind, the real nature and object of "the lap of the slide-valve."

In the construction of the diagrams, the condition that the case considered is that in which there is no angularity of the connecting-rod is continually kept in view by a novel and very neat and effective method of illustration. The diagram exhibiting the motion, is drawn upon and in direct connection with the valve, so that the effect of the eccentric in producing motion is made plainly visible at every step and throughout this course of instruction.

The author then goes on to treat of the motion of a valve operating one exhaust port only, and next shows how two valves may be connected, and operated by the same eccentric, whether both are steam, both exhaust, or one steam and the other exhaust.

It is next shown how, in the last arrangement, the action on the exhaust side is deranged, if the valve is made to cut off on the steam side. Finally the student is taught that when these "disjecta membra," of which the separate movements have been explained, are combined, they form substantially the common slide-valve with its fourfold functions, and that the latter presents no new features, with the two exceptions of the "lead" usually given it, and the "minus lap," which presents itself when the engine having lead is required to "follow full stroke."

The third chapter closes with the introduction of simple and easily comprehended diagrams, teaching how to construct geometrically the "movement" of the three-ported and of the two-ported valves.

Independent and slide expansion valves are next considered. When these valves are placed on the back of the main steam-valve chest, the principles involved in their geometrical treatment are, of course, merely those already explained, and their application is the same, with slight modifications introduced by the peculiarities of each case. When, however, the cut-off valve is carried on the back of the main steam-valve, the movement is usually less comprehended. Here the author has succeeded in presenting a very simple and easily understood illustration of it. and shows how the *relative* motion of the cut-off valve and its moving seat, is precisely that which would result were the latter at rest, and the former actuated by an eccentric rotating around the centre of the other eccentric, which, in fact, actuates the main valve. This novel and neatly effective method reduces the whole to a very simple problem, and it is easily seen that this device is practically identical with the preceding. Here, as in the other cases already referred to, the relative positions of the valves are depicted on the movement diagram, and the whole system is exhibited with admirable clearness.

The concluding chapter treats of the irregularities due to short connecting and eccentric rods, and teaches how to lay out the three-ported valve movement when it is desired to cut off at a given point, with the lead fixed for one end of the cylinder.

As a whole, the work is well adapted to the wants of a large class of readers. Its author uses it in instructing the classes of the Stevens Institute of Technology, and it will equally well meet the wants of other institutions of a similar character.—*American Artisan.*

ANALYTICAL CHEMISTRY.—A Course of Analytical Chemistry (Qualitative and Quantitative), to which is prefixed a brief treatise upon Modern Chemical Nomenclature and Notation. By WM. W. PINK and GEO. E. WEBSTER. London: Lockwood & Co., Stationers' Hall-court, Ludgate-hill. For sale by Van Nostrand.

Although the progress of the student of chemistry will always depend to a considerable degree upon the ability of the teacher, the use of a good outline treatise much lessens the labor of storing the facts in the memory in readily available form. A work well calculated to serve this purpose has just been issued as one of the volumes of Weale's educational series, and although extending to only 170 pages an enormous number of facts concerning both qualitative and quantitative analyses are carefully given. In the preliminary remarks concise information is given as to the theories adopted by the South Kensington authorities with reference to molecules and bonds, and there is a well-arranged list of the Frankland bonds of most of the common elements, classified according to their highest known atomicities, added to which is the very necessary explanation that, although an artiad can never become a perissad, nor a perissad an artiad, yet the pentads frequently take the form of triads or monads, and the hexads of tetrads or diads. Cases are given in which all the bonds are engaged, and the molecules complete, as well as of those in which the bonds are connected to the bonds of an atom of a similar element, those where we have a diad atom s bonds satisfying each other and forming a monatomic molecule, and those in which the two latter cases occur simultaneously. There is a list of the more important compound radicals, hydroxyl, hydrosulphyl, ammonim, ammonoxyl, sodoxyl, zincoxyl, and potassoxyl. These, with a couple of pages of rules for formulating, and a brief explanation of the

theory of equations, complete the introductory matter. The notes on general analysis are equally clear and concise, and a large mass of really useful information is given, which will enable the student to economize his reagents, and avoid damaging his apparatus. Ample particulars are also given as to the impurities to be looked for in the reagents, and the method of preparing them for use. The mode of separating the elements contained in a given compound into groups is, of course, given, and by the use throughout the book of various kinds of type, and the graphic formulæ usually of the science teachers of the Kensington School, the passing of the examinations used by educational departments will be much facilitated by using the book.

The volume is at once concise and explicit, and those who use it with the assistance of a science teacher, of even moderate ability, can scarcely fail to satisfy the examiners, and attain a creditable position in the class list.

A Manual of Inorganic Chemistry. The Non-Metals. By T. E. Thorpe, Ph. D. London and Glasgow: W. Collins, Sons & Co. For sale by Van Nostrand.

The collection of facts which constitute the modern science of chemistry is so immense that it is not surprising that Professor Thorpe has been compelled to divide his text-book into two volumes. The work before us is one of Messrs. Collins' advanced series, and it is admirably calculated to fulfil its design of fitting a student to take part in a study of current chemical literature and theories. The author has wisely not contented himself with a *résumé* of well known facts, but has consulted the most recent memoirs of original researches, and has contrived to give, in a small space, an excellent survey of chemical facts and philosophy. This book, besides being one of the cheapest, is also one of the best for the student intending to submit to the Advanced or the Honors Examination in Chemistry of the Science and Art Department.

The Ocean: its Tides and Currents and Their Causes. By William Leighton Jordan. London: Longmans, Green and Co. 1873. For sale by Van Nostrand.

There is no more vexed question in physics than that which concerns the causes of the great ocean currents. For a time long in the age of modern science the piling up of the waters of the Atlantic in the Mexican Gulf was universally accepted as the moving why of the best known of the great salt-water rivers, whose banks are also composed of the liquid element which covers five-sixths of the surface of the globe, and forms the highway of the nations; then Captain Maury, and after him Dr. Carpenter, produced their theories, all of them seeking the solution of obvious facts in more or less obscure causes. The author of this book, however, rests his theory upon a cause cosmical in its origin, which he styles "vis-inertiæ," and holds to be "a really inherent property in matter, by virtue of which it endeavors to be just what it is and where it is"—the conservative principle in nature, obviously—"and that gravitation is simply an effect of vis-inertiæ." And on this principle, like the ancients with their abhorrence of nature for a vacuum, he accounts not only for the currents, but the tides both of the ocean and the atmosphere, and not only for these, but for the entire motions of the stellar and planetary bodies—gives us, in fact, a new "Principia.' Still, the book is the production of a man thoroughly well up in his own subject, and many others collateral with it; but from the nature of the argument it is difficult of popular explanation within the limited space at our disposal. It is one, however, that may be safely commended to the study of all who are interested in the subject of ocean currents, regarding which we think we may safely affirm that no hypothesis yet offered covers all the facts of the case.—*Iron.*

MISCELLANEOUS.

Concrete Construction.—In the Report by Mr. Thomas Hawksley, past-President of the Institution of Civil Engineers, on the Chester Sewage Works, which was read at the meeting of the town council on January 14, we find the following reference to the system of concrete construction adopted in part of the works:

"The tanks have been designed in a somewhat unusual way, probably with a view to economy; but in my judgment, even in this view, not very successfully. Cement concrete has been resorted to as a substitute for brickwork, and as a substitute it may succeed well enough, provided the persons engaged in the necessary manipulations have had much previous experience in the use of the materials, and take a real personal interest in their work. For my own part, I should have preferred good brickwork for this purpose to any construction of concrete. I do not, however, wish to intimate that there is any danger of the concrete work failing, provided the labor and materials be really of the superior kind to which I have thus alluded. Questions had arisen and were put before me upon this particular subject, and they became extended to the qualities of the lime concrete, and of the mortar as used in the work. I proceed to answer those questions:—

First, as to the cement concrete. This concrete was stated to have been composed in the following *measured* proportions: Gravel, six parts; sand, one part; cement, one part. If the cement were reliable, these proportions ought to result in a first-class concrete. I was informed that the prescribed cement had been difficult to obtain, and that a cement made from the lias limestone of Warwickshire had been used instead. I prefer the lias cement, assuming it to have been properly manufactured, and therefore do not think that the engineer has been unwise in permitting the substitution.

Second, as to the lime concrete. This I understand to have been made in the following measured proportions: Gravel, five parts; sand, uncertain and variable, but small in quantity; Rugby or Holywell ground lime, one part. These proportions form a rich concrete which might have been improved in its finally hardening properties by a larger proportion of sharp sand. I prefer also that the lime and the sand shall be made into a well-mixed mortar before being added to the gravel. The strength of all concrete depends upon the intimate blending of angular sand with the cementitious matter, for without that a proper crystallization is not set up.

Third, as to the mortar. This was stated to

consist of: Lime, two parts; sand, two parts; cinders, one part. This was not a good material. The sand was in fact crushed sandstone, and the cinders were really slags of steam boilers. These were ground with the lime under edge-stones till the whole was reduced to an impalpable mixture, rather of the character of a limey mud. For the reasons already stated, the sand should have been sharp, silicious, and angular, whilst, as I understand, the cinders should have been smith's ashes containing the usual proportion of iron oxide. Hand-made, or well-pugged mortar is to be preferred for engineering purposes to finely crushed mortar.—*Architect.*

EVALUATION, IN MECHANICAL UNITS, OF THE QUANTITY OF ELECTRICITY PRODUCED BY AN ELEMENT OF A PILE.—M. Branly.—The object was to estimate, in electrostatic measure, the quantity of electricity passed, in a second, by an element of a pile, in a circuit of given resistance. An insulated metallic sphere received, m times per sec., a constant charge A, which was removed each time, by putting it in communication with the ground by the bobbin of a Ruhmkorff galvanometer. The quantity of electricity, m A, traversing the bobbin, deflected the needle; and this deflection was compared with that produced by the flow of electricity from a Daniell element in a known circuit (the method of doing this is detailed . It was verified that the charge of the sphere is proportional to the radius of the latter, and to the potential of the pile, and that the deviation is proportional to the number of discharges (at least within certain limits). After these preliminaries, the author gives numerical particulars of one experiment The number obtained for m A is 104,699 units of electricity. The current produced by 104,699 units passing each second to the earth gave a deviation measured by the number 51.25. The current of a Daniell element was passed in a circuit of 1,000 kilometres; and the two wires of the galvanometer were connected to two points of the circuit, comprising, between them, 1 kilometre. The resistance of the galvanometer being 336 kilometres, and the intensity of the principal current being represented by 1, that of the derived current which traversed the galvanometer was about $\frac{1}{336,000}$; for the double deviation (current reversed) the reading was 371.4. It may then be said that the current whose intensity is $\frac{1}{336,000}$, causes to circulate, in 1 sec., a quantity of electricity represented by $104699 \times \frac{371.4}{51.25}$ units. Before giving a definite number for the constant to be measured, the author proposes to determine, with more precision than he had been able to do, the absolute resistance of the bobbins used.—*Tel. Jour.*

ON THE LOSS OF MAGNETISM.—M. Jamin.—Coulomb has shown that a magnet, heated successively to increasing temperatures, preserves after cooling only a portion, less and less great, of its primary magnetism. The general opinion is, that at a temperature t, steel takes a determinate magnetization, which is less as t increases, and which it retains on cooling. But the phenomena are in reality more complex and curious. M. Jamin takes a bar of tempered steel; transfers it to a sand bath, where it receives the blue color of springs; then introduces it rapidly into a bobbin of electric wires traversed by a current of 20 elements; and by means of straw suitably arranged, he prevents, or at least retards, cooling of the apparatus. The steel takes a total magnetization slightly less than if it were cold. Then he breaks the circuit, and measures immediately the force of detachment of a contact placed at the end; *i. e.*, the remanent magnetization. Not only is the steel thus magnetized in the hot state, but its remanent magnetism is much greater than that which it is capable of preserving when it is cold. It is equal to 109 grammes, instead of 54. It is not correct, then, to say that the coercitive force diminishes with heating; the contrary occurs. But if one commences to measure the force of detachment minute by minute, it is perceived to decrease at first very rapidly, then less rapidly, and in a quarter of an hour it has wholly disappeared. This occurs not only when the magnet is maintained at its primary temperature, but when it is allowed to cool naturally, which takes place very slowly. There is not, then, for each temperature, a determinate magnetic state decreasing as the heat increases. The passage is almost continuous from total magnetization, represented by A B (line parallel to abscissa in figure given), to the remanent magnetization represented by B C D (curve concave upwards, descending towards zero as the time increases. There is a veritable magnetic loss which is gradual, which resembles the loss of heat in cooling, and may be well enough represented by Newton's law $y = e^{-ax}$. Now heat the bar, but to a less temperature, and re-commence the initial magnetization. While the current passes, it is represented by E F (a line higher than A B; but immediately the current ceases, it falls to G (a point some distance below B); it is less than formerly; but, on the other hand, it is weakened less quickly, and is not totally lost; there remains after cooling, a portion which is the greater the less the bar has been heated. Lastly, M. Jamin compares the case in which the bar is not heated. It has a total maximum magnetism K L (line higher than E F), and a remanent magnetism, the smallest possible, and not sensibly varying with the time.—*Tel. Jour.*

WESTERN ILLINOIS BRIDGE.—The plans for the proposed new bridge over the Mississippi at Quincy, Ill., have been prepared by the American Bridge Company of Chicago. It is to be a double-deck bridge with railroad track below and highway above. There will be a draw-span of 300 ft., one fixed span of 250 ft., the other fixed spans being 160 ft. each, and the whole length of the bridge about 2,400 ft.

NOTE.—The article on "Fuel," in the present number of the Magazine, is substantially the same as the article bearing the same title in the last volume. It was received in pamphlet form from a prominent engineer with a request to re-publish entire. It was accordingly sent to the printer, under the impression that the former publication was an abstract only, and was possibly too brief for so valuable an article. A comparison of the two, however, shows that our first was so complete as to have rendered the second publication unnecessary in our columns. The discovery was made too late to effect a change.